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A Guidebook for Preparing Agricultural Water Conservation Plans

ACHIEVING EFFICIENT WATER MANAGEMENT

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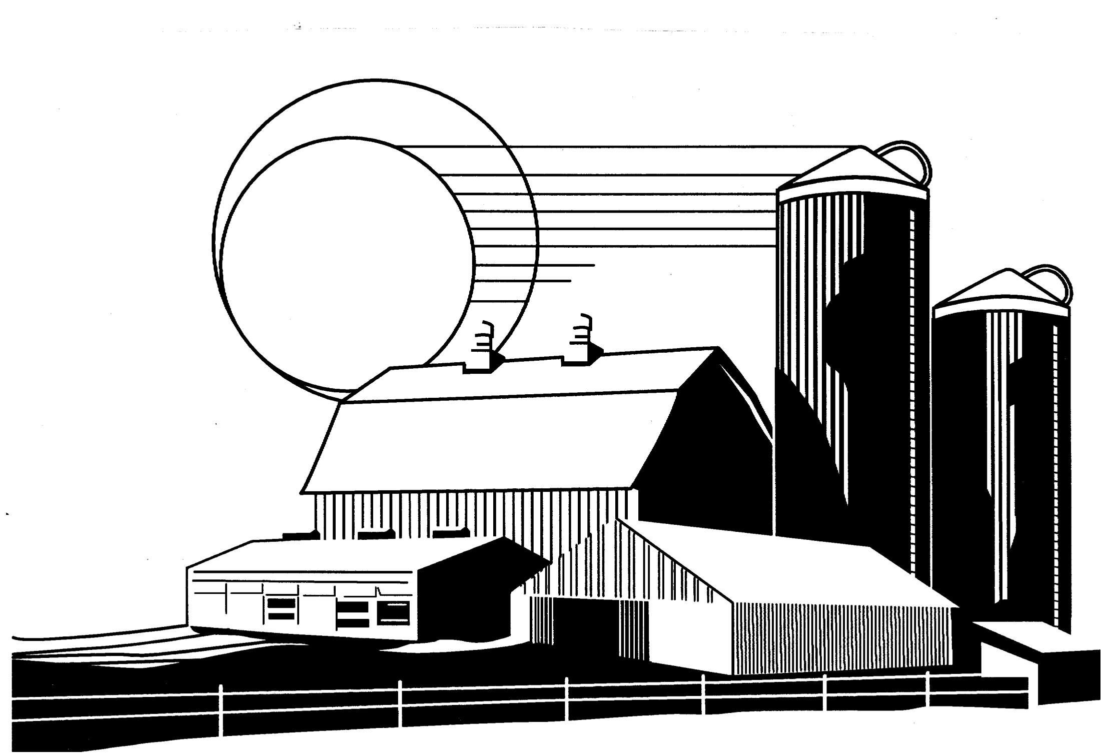
Abbreviations and Acronyms

af	acre-foot
Act	Clean Water Act
CAP	Central Arizona Project
CCID	Central California Irrigation District
CIMIS	California Irrigation Management Information System
CVP	Central Valley Project
Districts	Arnold and North Unit Irrigation Districts
EA	Environmental Assessment
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
ESA	Endangered Species Act
ET	evapotranspiration
FIRI	Farm Irrigation Rating Index
Guidebook	*A Guidebook for Preparing Agricultural Water Conservation Plans: Achieving Efficient Water Management.*
Handbook	*Incentive Pricing Handbook for Agricultural Water Districts.*
IMS	Irrigation Management Service
M&I	municipal and industrial
maf	million acre feet
MWD	Metropolitan Water District of Southern California
NEPA	National Environmental Policy Act
NRCS	Natural Resources Conservation Service
NCWCD	Northern Colorado Water Conservancy District
O&M	operation and maintenance
Reclamation	U.S. Bureau of Reclamation
RRA	Reclamation Reform Act
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
Warren Act	Warren Act of February 21, 1991
WCUA	Water Conservation and Utilization Act

Section One -- Introduction

This section provides an overview of what this Guidebook is about, including:

- ☞ Why the Bureau of Reclamation prepared this Guidebook
- ☞ Water conservation versus water management
- ☞ Who should use this Guidebook
- ☞ What is good water management
- ☞ Why do water management planning
- ☞ Organization of the Guidebook



WHY RECLAMATION PREPARED THIS GUIDEBOOK

The Bureau of Reclamation prepared this Guidebook to help agricultural water districts and irrigation organizations prepare water conservation and management plans to achieve more efficient water use. The Guidebook is aimed at organizations of all sizes and complexities, both Federally-supplied and private.

Products such as this manual support and strengthen Reclamation's overall water management mission. Through products such as this, Reclamation hopes to cooperatively work with others to improve water resource management and the efficiency of water use throughout the western United States. In particular, this manual supports Reclamation's responsibility under the Reclamation Reform Act (Sections 210a and 210b) and other Reclamation law, to encourage more efficient water use by the districts it serves.

WATER CONSERVATION VERSUS WATER MANAGEMENT

One objective of this Guidebook is to help districts prepare water conservation plans called for in Section 210 (b) of the Reclamation Reform Act. However, the methods and measures described in the Guidebook are more broadly aimed at helping districts improve their overall water management. Improved water management will often lead to better water conservation. We encourage you to take this broader view as you use this Guidebook.

WHO SHOULD USE THIS GUIDEBOOK?

This Guidebook is meant to be used by irrigators, the managers and staff of irrigation organizations, States, and others to improve water management at the farm and the district level. Throughout this Guidebook, the term “you” refers to district management and staff members responsible for preparation of water management plans.

WHAT IS GOOD WATER MANAGEMENT?

To the farmer, good water management means getting the right amount of water to the crops at the right time with minimum labor and expense. If this can be accomplished without creating other problems, such as a build-up of salt in the soil or losing water to spills and seepage, so much the better.

To the irrigation district or ditch company, good water management means meeting the water needs of its customers as efficiently as possible, with minimum waste or loss. Good *water* management is therefore fundamentally important to good overall *district* management.

To society, good water management means having adequate supplies of good quality water for all municipal, industrial, agricultural, recreational, and environmental needs. Those in charge of operating water supply and delivery systems bear the greatest burden of responsibility for promoting and achieving the good water management demanded by society.

WHY DO WATER MANAGEMENT PLANNING?

Planning is the process of thinking ahead to achieve desired future outcomes and to avoid undesired future pitfalls. It is something we all do at many levels every day of our lives. There are benefits to be gained and risks to be avoided by water management planning.

Benefits of Good Water Management Planning

Water management planning can benefit both the irrigation district and the irrigator, as well as third parties and the environment. The range of potential benefits includes:

- Better water service to customers
- More effective use of available water supply
- Reduced operating costs
- Improved revenues to the district
- Improved crop yields and quality
- Reduced on-farm costs
- Development of additional water supply capabilities
- Improved water quality and aquatic habitat
- Habitat maintenance for endangered species
- Better documentation of uses and accomplishments
- Education of customers and the public
- Diminished groundwater overdraft
- Improved system and water supply reliability
- Postponed need for new or expanded water supplies
- Reduced drought impacts

Pitfalls Avoided by Good Water Management Planning

There are a variety of problems and pitfalls that can be avoided by good water management planning. Some of these could affect the district and its customers immediately and others could pose future threats. Some examples of undesirable situations that might be avoided through good planning are:

- Daily and seasonal water shortages
- Excessive losses or spills from water delivery systems
- Over- or under-application of water on farm fields
- Insufficient carryover supplies in reservoirs
- Loss of water rights through waste or abandonment
- Adverse relationships with other water users and publics
- Drainage and erosion control problems
- Ill-timed water deliveries to farm fields
- De-watered streams and wetlands

Organization of this Guidebook

This Guidebook is divided into four main sections. Each section is separated by a tabbed divider page making it easy to turn to a specific area of the Guidebook.

Section One is this introductory section of the Guidebook.

Section Two describes a step-by-step planning process that will enable you to identify the most effective water management improvements to make first.

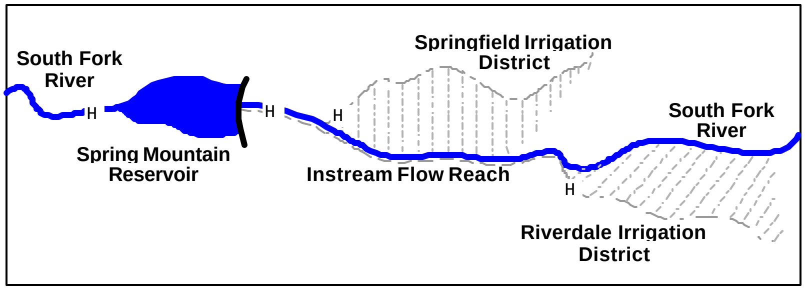
Section Three contains brief descriptions of a range of agricultural water management measures. It contains questions and checklists to help you decide which measures might best apply to your situation.

Section Four is a brief guide to preparing a water management plan document for your Board of Directors, operations staff and customers, and for others. It contains a suggested outline for the document and provides examples of how different types of information might be presented.

At the back of the Guidebook, you will find a glossary of terms, lists of references and contacts for further information and assistance.

In order to help you better understand the concepts and methods presented in this Guidebook, we have created a "story" about a hypothetical irrigation district. This story, which appears in a series of boxes such as the one below, describes how the district goes about developing a water management plan. The resulting plan is shown as an example in Section Four.

Springfield Irrigation District is a small irrigation district in the West established in the early 1900s. It diverts below Spring Mountain Reservoir on the South Fork, a stream that peaks during spring runoff. For irrigation, the district uses its natural flow water rights in the early season and takes storage water in the late season. The climate and soils are such that Springfield's farmers grow mostly alfalfa, grass hay and corn. For the most part they use flood and contour ditch irrigation methods.



Every farmer in the district pays assessments based on the number of acres he or she owns. The district uses these assessments to fund operations and capital improvements, but for the past several years the assessments have gone almost entirely to repairing the same section of the main canal. A growing number of farmers in the district are complaining that their annual assessments aren't being fairly applied to improving services. One of these farmers, Sid, is on the district's Board of Directors.

Another growing problem is the district's relationship with the local community. A recent *Springfield Herald* headline read, "District Draws Reservoir Down, Marina Left High and Dry." Though the district has been operating the same way for decades, it is suddenly facing more and more criticism from the public.

This year, to address these and other district problems, Springfield's district manager, Ron, has decided to propose that the district develop a water management plan. He intends to sell his idea of a water management plan to the Board of Directors by pointing out that, not only will they finally address the farmers' complaints, they will avoid mistakes made in the past when they took too narrow a view, they'll improve their image with the public and they'll be a step ahead of other districts in the basin when it comes time to seek project financing and renegotiate water supply contracts.

Section Two -- The Planning Process

This section of the Guidebook will introduce you to the planning process. It will:

- ☞ Outline a systematic but flexible planning process
- ☞ Help you identify water management problems and goals
- ☞ Help you evaluate potential ways to solve problems and achieve goals
- ☞ Help you decide what water management improvements should become part of your action plan

OVERVIEW

Planning is just a logical sequence of decision-making phases or activities that include:

1. Gathering Information & Defining Problems
2. Setting Goals & Priorities
3. Evaluating Options
4. Defining a Plan of Action
5. Implementing & Monitoring

There is nothing magical or complicated about this sequence of activities. If you think about it a little bit, you will realize that you use this thought process for almost every decision you make. In the context of water management, it is simply used as a framework to ensure a systematic and thorough decision-making process.

The five planning phases described above are shown in sequential, step-by-step order. However, the planning process often requires going back and forth between steps. For example, it is very common to determine, in the course of evaluating options, that further information gathering is needed.

It is this back-and-forth approach that makes planning a process, as shown in

Figure **1**, rather than a product. The product (in this case a water management plan) should be viewed as a "snapshot" of an ongoing process, taken at a specific point in time for the purpose of implementing particular management measures.

Water management planning should be viewed as an ongoing activity and not as a one-time effort. Situations change, new technologies arise, and problems and opportunities may be seen in a new light. As a result, plans become outdated. Water management planning must become a routine part of district management to be effective in the long run.

Each of the five planning phases shown on

Figure **1** are discussed in detail in this section. Hopefully, by the time you have read through the section, you will have a good understanding of the planning process and how it could be applied to your situation.

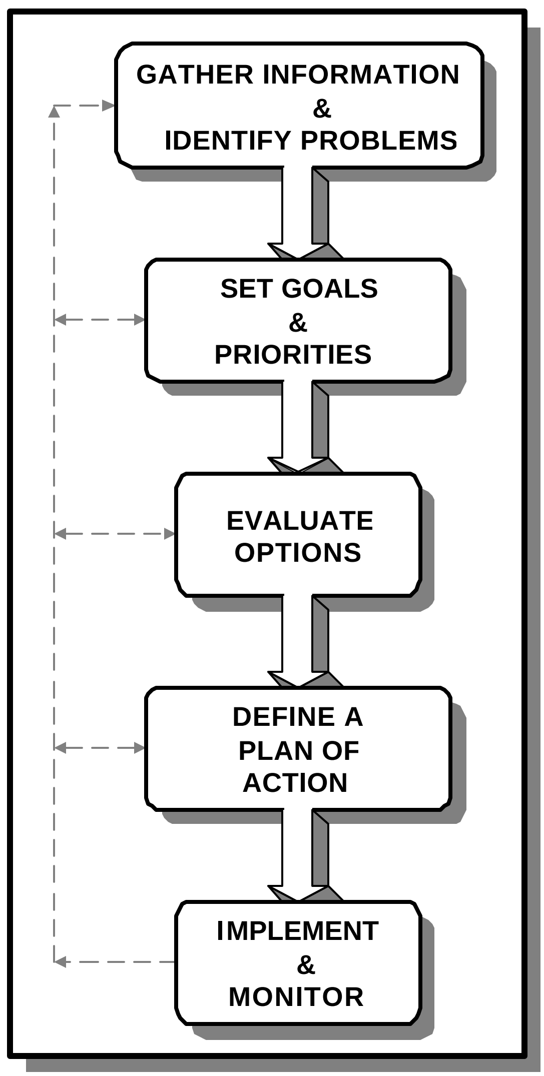


Figure 1: The Planning Process

The Importance of Public Involvement

A basic principle of planning is that it cannot effectively be done in a vacuum. It would be foolhardy to design a new set of policies, procedures, or requirements and attempt to implement them without involving the people affected by them. In many cases, district or ditch company bylaws would prohibit such actions.

For plans to be credible and effective, it is important to obtain consensus and support from district boards of directors and from potentially affected parties. The parties that are most obviously affected by the water management measures described in this Guidebook are water users themselves. Involving water users in all phases of the planning process is more likely to produce management plans that address real problems in practical ways. If they feel that the plan is responsive to their needs and to their input, they will be far more likely to support it.

But there are other important "publics" that can also make significant contributions to plan development. Involving local community leaders, state and federal agency staff, and representatives of various interest groups in the planning process is more than the application of the "two heads are better than one" principle; it also provides a mechanism for obtaining broader perspectives on the issues and can help head off later obstacles to plan implementation.

For these reasons, it is very important to consider public involvement as an integral part of the water management planning process. The goals of public involvement are:

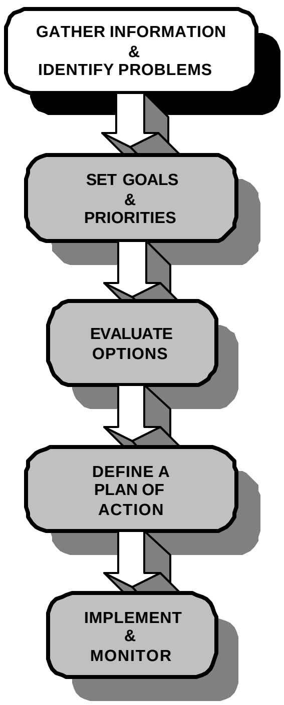
- To build credibility by establishing an open and accessible planning and decision-making process

- To identify and understand the diverse concerns and values of the parties potentially affected by your decisions

- To develop a consensus among these divergent interests in support of your water management plan

Some methods to provide public involvement opportunities include mail questionnaires and information sheets, public meetings and workshops, focus groups and advisory committees, and the use of local media. Reclamation has a substantial amount of experience in developing public involvement programs and has produced a *Public Involvement Manual* to assist water resource planners in this area (USDI, 1980). Additional assistance in developing a public involvement program can be obtained from the Water Conservation Coordinator at Reclamation's Area or Regional office nearest you.

PHASE 1 -- INFORMATION GATHERING & PROBLEM DEFINITION



Overview

The first phase of the planning process includes problem definition and information gathering activities. These activities go hand-in-hand. You probably already have some ideas about water management problems in your district, but having more or better information will help you define those problems more clearly, and possibly uncover others. You also probably already have quite a bit of information about water use in your district, but it may be incomplete or not organized in a way that is helpful in problem-solving.

This first phase of the planning process is meant to "flesh out" information gaps and uncertainties about problems and to develop a solid foundation for subsequent planning activities. Before you can effectively set goals and evaluate options, you must have a clear definition of the problem you are trying to solve.

Input from irrigators and others affected by your district's water use will help you identify important issues. When examined carefully, these issues may turn out to be symptoms of more basic problems. Therefore, you will want to involve a wide range of people at the onset of Phase 1, perhaps through an annual shareholder meeting or public meeting.

Checklist of Information Needs

Part of the first phase of the planning process is gathering the information you need to identify and analyze water management problems. You also will need some other descriptive information about the district to include in your water management plan document so that people who read it have a good understanding about the district. The checklist below is provided to help you get started assembling the information you will need.

Physical Setting

Understanding the local hydrology and climate will help you identify the factors which affect district water supplies and irrigation demands. Data that might be useful include:

- Hydrology of source streams, district reservoirs, area wetlands and groundwater
- Water quality of sources and return flows
- Climate information such as precipitation and temperature

Sources of hydrologic, climatic, and water quality data include extension offices, local universities, the National Climatic Data Center, the US Geological Survey, the EPA, the NRCS, Reclamation, and private data publishers.

Water Rights, Permits, and Contracts

The legal and institutional constraints under which your district operates will be a factor in your water management plan. Therefore, it would be useful to understand:

- Rights or permits held by the district
- Contracts with Reclamation or others
- Instream flow requirements
- Restrictions on water use
- Endangered Species Act compliance needs

Sources of information include district bylaws, articles of incorporation, decrees, contracts, and state water legislation. Pay particular attention to restrictions on the use of conserved or salvaged water, transfers within your district or between districts, and any requirements to preserve return flow patterns.

Lands and Crops

Understanding the agricultural details of your district is key to developing a sound management plan. Data that should be collected include:

- Acreage under each crop
- Irrigation methods
- Soils, topography, and drainage

The Crop Production and Water Utilization Data sheets that districts submit to Reclamation are comprehensive with respect to areas irrigated and crops grown. You should find descriptions of terrain, soil types, and soil parameters important to irrigation operations in Reclamation's Land Classification Maps. Your district may have copies of these maps or may wish to obtain them from Reclamation's area office manager. Other sources of soils information may be found in Natural Resources Conservation Service (NRCS) soil surveys.

District Operations and Operating Policies

Your water management plan may involve modifying existing operating policies. Sources of this information include district bylaws, written policies, district rules and regulations, and standard practices. You will first need to understand:

- General operations
- Water ordering and delivery procedures
- Water shortage allocation policy
- Inter-district agreements and operations

- Staffing and training of operators

Examples include reservoir operations, main canal operations, timing of use of different sources, groundwater pumping policies, flood control policies, facilities maintenance, and hydropower operations. Many operating policies may not be written down; describing your operations in writing will help you and others better understand how the district works.

Water Pricing and Accounting

To understand relationships between water use and revenues, you will want to compile descriptions of:

- Water accounting procedures
- Water user billing procedures

These procedures may be gleaned from standard practices or they may be codified in bylaws and contracts. If some of your district revenue comes from billing water users, you will want to understand the basis for billing.

Water Resources Inventory

The infrastructure and water supplies currently in place in your district will be the most important factors in determining where water use efficiencies can be improved. Records of flow amounts will be key to estimating losses and potential savings. The types of data you will need include:

- Diversion capacities and diversion records
- Groundwater pumping capacities and pumping data
- Storage capacities, storage and release records, and evaporation data
- Delivery records and data, including peak period deliveries

- Drainage and return flow records

Some districts will have detailed, daily records for diversions, storage and deliveries for multiple points in the system. Others will have diversion and delivery records only for main canals and laterals. Reclamation's Monthly Water Distribution sheets will contain monthly data for your district, though the accuracy and reliability of these data should be verified. You may also have additional records in the form of ditch rider notebooks, water ordering cards, etc. Information from drought years will be particularly useful.

Other Water Uses

There may be opportunities and constraints presented to your district by non-agricultural water uses. Your district may provide water supplies for municipal, domestic, or industrial uses; you will want to quantify those water uses as much as possible. Some other water uses include:

- Recreational and environmental uses
- Special needs or operations (e.g., sediment flushing)

Existing Water Management and Conservation Programs

You will want to understand what management measures or programs have already been implemented in your district. These could range from sprinkler installation to education programs to variable rate pricing. Understanding the cost and impacts of each measure will help you make informed decisions about future measures. Lessons from programs that have not succeeded are as valuable as those from programs that have succeeded.

Identifying Problem Areas

There are a variety of ways to learn about water management problems in your district. Probably the most common way is day-to-day observation and experience. District management and staff members often observe operational problems directly. Water users may complain of difficulties with deliveries. Other persons in the community may bring drainage problems to your attention. Holding informal “brainstorming sessions” with district staff, water users, partners, and stakeholders might help to increase information exchange.

> Ron discusses his planning ideas with the district’s Board. The Board is interested in the concept but wants to find out how much support there might be for it in the district. Together they decide that they need a meeting with the farmers to introduce the idea of a water management plan and to identify key district problems. Sid suggests that they expand the district meeting to include the public.
>
> Ron wants this public meeting to be an opportunity for the farmers and the local community to thoroughly vent their concerns and ideas. He makes a brief presentation to the audience and then opens it up for questions and comments. He asks one of the participants to record the comments and suggestions on sheets of butcher paper displayed for everyone to see.
>
> Some of the more frequent comments are:
>
> - There isn’t enough canal capacity to get water to the lower end of the district.
> - There isn’t enough late-season water.
> - We’d like to grow more corn but we need to get the water on a more timely basis.
> - There are big seepage losses in portions of the canal.
> - The seepage losses have supported wetlands for almost 100 years.
> - A lot of water is lost when farmers shut off their laterals and the canal spills.
> - Let’s look at what other districts are doing before launching into a big program.
> - Efficient irrigators are paying a lot more per acre-foot of water than others are.
> - Boaters and fishermen at Spring Mountain Reservoir are pushing for higher, late-season lake levels.
> - The state wants to improve the springtime streamflows in the section of the South Fork just below Springfield’s headgate.
> - We don’t have a lot of money to spend.
> - Downstream municipal users are concerned about the quality of drainage and return flow water.
>
> After a couple of hours of collecting farmers’ ideas, Ron suggests that a handful of farmers volunteer to form an advisory committee. He gets three volunteers, Sid, Iris and Wendell.

Another important way to learn about water management problems is to analyze data. For example, by comparing records of gross diversions with records of farm deliveries you can estimate the amount of water lost in main canals and laterals. This type of quantitative analysis can provide quite specific information about problem areas, provided it is based on accurate data. One very useful method of analysis is the water budget, which is described in more detail below. You also might be able to obtain additional useful data from other agencies (for example, a county extension agent) or by installing new measuring devices.

The Water Budget Concept

The water budget is a convenient tool for analyzing water management problems and opportunities, provided that you have adequate and reliable data. It is also a useful way to organize quantitative information you have collected.

The water budget concept, simply stated, is that the sum of system inflows has to equal the sum of system outflows. Inflows consist of all the sources of water supply to the district. Outflows consist of all the ways that water is removed from the district. The various components of inflow and outflow that are usually present in a district water budget are shown in Figure 2.

By comparing inflows and outflows in a water budget, it is possible to identify unaccounted-for losses. For example, if the diversion into a canal and farm turnouts from the canal are all measured, the difference between the diversion and the sum of the turnouts would be the gross loss from the canal. This gross loss is the net result of seepage, evaporation, precipitation, and the interception of surface runoff and groundwater flow. If any of these latter quantities (such as precipitation, evaporation, and interception) can be accurately measured or estimated, then the remaining difference provides an estimate of the other quantities (such as seepage).

However, all this is possible only if the records or estimates for all the accounted-for inflows and outflows are accurate and reliable. If any of those records or estimates are unreliable or inaccurate, the losses calculated from the water budget will also be unreliable or inaccurate. Thus it is very important that the data used in water budget analysis be verified. Figure 3 illustrates the extent of flow measurement that is desirable for development of a good district water budget.

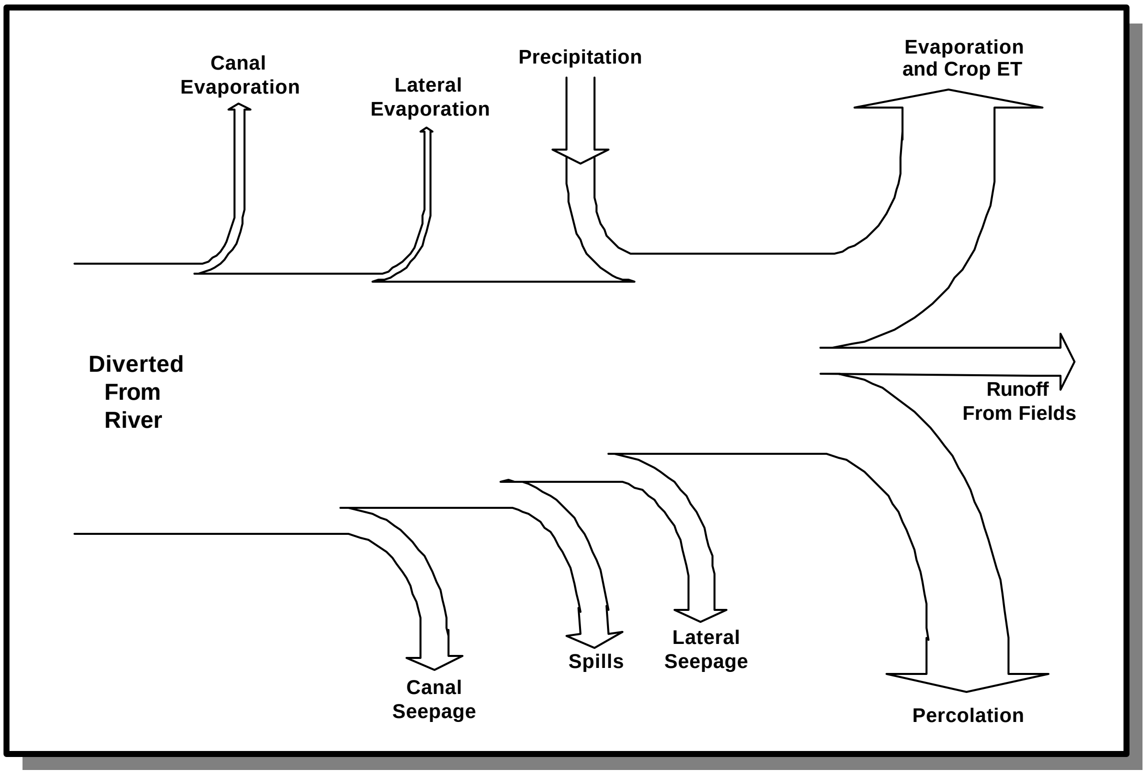


Figure 2: Typical Components of a Water Budget

The water budget approach is very flexible and can be applied at different scales. For example, it can encompass the entire district or focus on a specific lateral. By focusing on smaller areas, it is sometimes possible to identify the specific locations of problems such as ditch seepage.

The water budget can also be prepared on an annual basis or a daily basis. A shorter time step sometimes helps identify scheduling problems. Table 1 depicts a water budget set up to look at an entire district on a monthly basis for an average year. It might be helpful to prepare such a water budget for a wet year and for a dry year to see how losses change with hydrologic conditions. By analyzing several years, your confidence in the results of the analysis will be increased.

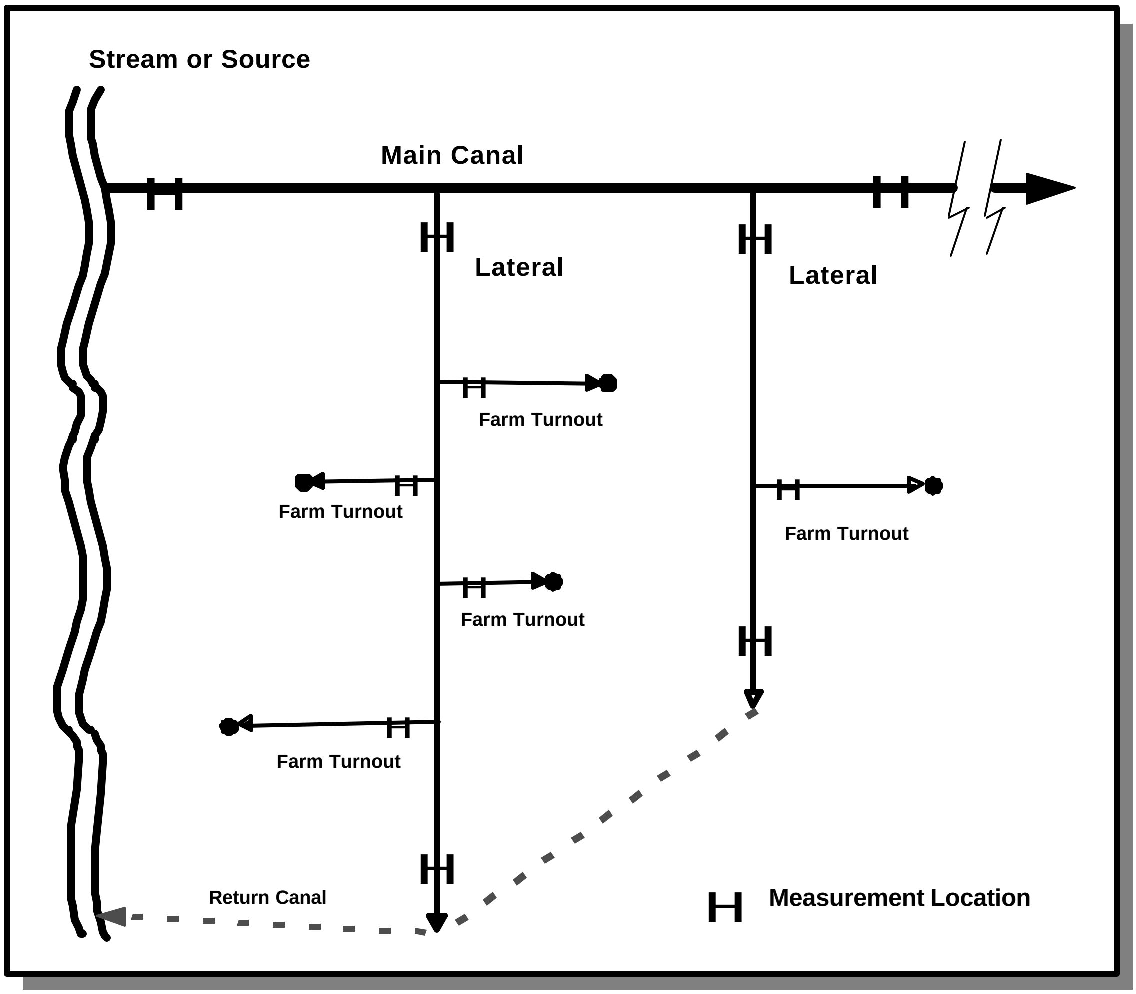


Figure 3: Ideal Water Measurement System

The primary limitation on what scales can be used in the water budget is the availability of accurate flow measurements. You should not be tempted to stretch the application of the water budget methodology beyond what you have the data to support. If you are unable to construct a good water budget for the district, you should probably consider the improvement of water measurement systems to be a top priority for your water management plan.

The Crop ET value in Table 1 can be calculated from crop acreages and crop consumptive use estimates.

Consumptive use estimates are often available from Reclamation or other state or local agricultural agencies. Most districts don't collect seepage and evaporation data. These values may be derived from the water budget if the other data in the table are available.

Table 1: Example Monthly Water Budget

	INFLOWS					OUTFLOWS				
Month	Direct Diversion	Storage Release	Ground Water Pumping	Precipitation	**Total Inflows**	Operational Spills	Drainage	Evap. & Seepage	Crop ET	**Total Outflows**
Jan	0	0	0	1200	1200	0	720	480	0	1200
Feb	0	0	0	1500	1500	0	900	600	0	1500
Mar	0	0	0	2250	2250	0	1350	900	0	2250
Apr	3581	0	0	2700	6281	1053	527	1053	3648	6281
May	8723	0	0	2550	11273	1491	1491	1988	6302	11273
Jun	9318	0	0	750	10068	705	1411	1411	6541	10068
Jul	9629	4395	550	450	15024	1053	2107	2107	9757	15024
Aug	5777	7770	400	300	14247	1208	2416	2416	8207	14247
Sep	2889	4101	0	600	7589	611	1221	1221	4536	7589
Oct	654	978	0	750	2382	195	389	389	1409	2382
Nov	0	0	0	750	750	0	450	300	0	750
Dec	0	0	0	1050	1050	0	630	420	0	1050
Total	40571	17244	950	14850	73614	6316	13612	13285	40400	73614

One of the most valuable aspects of the water budget is that it provides a means to calculate efficiencies. Estimating efficiencies at different levels will help you identify where improvements are needed the most:

DISTRICT-WIDE EFFICIENCY = CROP ET ¸ TOTAL INFLOWS

DELIVERY EFFICIENCY = TOTAL FARM DELIVERIES ¸ TOTAL INFLOWS

ON-FARM EFFICIENCY = CROP ET ¸ TOTAL FARM DELIVERIES

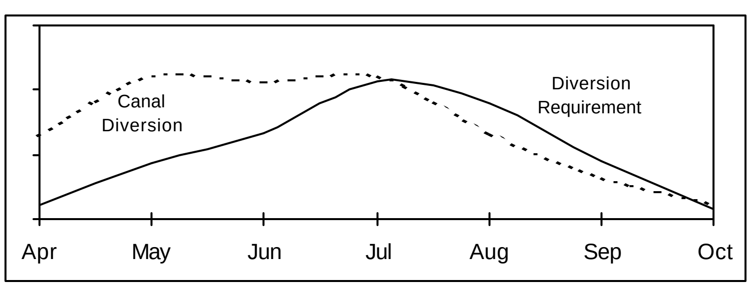
Monthly calculations of efficiencies will help you determine how well district diversions and deliveries match crop requirements.

Ron meets with the advisory committee to go over the list of issues identified at the district-wide meeting. It seems like there is some confusion about when and how much water is actually getting to the farmers, and when and how much water is lost. Ron has been to a few Reclamation workshops on water management and has an idea about doing a water budget for the district to help them pin it down better. They don't have much data but they do have several years of annual Crop Production and Water Utilization Sheets that they've submitted to Reclamation. These sheets have monthly estimates of how much water was diverted by the district, how much was lost in conveyance, how much was spilled and how much was delivered to farms.

The only flows that are measured regularly are those at the main canal diversion from the South Fork. Flows into some of the farm turnouts can be estimated based on the gate opening, but measurements aren't taken consistently. No measurements of spills or transportation losses are made anywhere in the district. To fill out the Water Utilization Sheets, the district has been using ditch riders' estimates of deliveries. Not surprisingly, Ron and the advisory committee are somewhat skeptical about using the loss and farm delivery data in the Water Utilization sheets.

Iris proposes that they take a slightly different approach to the water budget, "What if we compare the monthly canal diversion amounts with crop irrigation requirements? At least we have confidence in the diversion data, and I've heard that crop requirement estimates are available from the county extension agent. If we multiply the requirements by the number of acres under each crop type we'll get an estimate of the district-wide requirement."

This water budget analysis method shows that the difference between the monthly canal diversion and the monthly irrigation requirements is surprisingly large. Wendell points out that the district diverts much more in the early season than is necessary for the crops. "No wonder the reservoir is so low at the end of the season, our natural flow diversions are competing with its storage right," he says.



Sid says, "I think we take a lot of water early because folks are worried that our water rights will be in jeopardy if we don't take as much as we can, when we can."

"Hmm, I don't know," wonders Ron, "At the most, we only need to take the decreed amount once in the season to protect our right. Do we divert so much early on because we need that much water to bring soil moisture levels up? Where is that water going? Boy, I wish we had better data."

Checklist of Typical Problem Areas

A "checklist" is provided below to help you start thinking about where there might be opportunities to improve water management in your district. This checklist is organized into problem areas that are common in irrigation organizations. It may be that your district or ditch company has unique water management problems and opportunities that could be added to this list.

Adequacy of Data

Good information is fundamental to making good decisions. Informed decisions about water management are based on good water measurement and accounting. Without accurate and reliable information about when, where, and how much water is used, it is difficult to correctly assess the locations and magnitudes of problems. These assessments, in turn, are key to deciding how to allocate scarce district resources.

? **Do you make regular measurements of flows into all laterals? To your turnouts?**

? **Are all measuring devices in good operating condition? Checked regularly?**

? **Are you able to base billing to customers on measurements of water they actually use?**

? **Do you think you could use more or improved water measurement?**

? **Do you have specific ideas about where and how such measurements should be taken?**

Adequacy of Supply

The adequacy of the district water supply should be considered at several levels. In some situations it will be clear that water demand chronically exceeds available supply. However, it is more common that supply is adequate on the average, but there are shortages in dry years, in the late season, or in certain locations.

? **Do you regularly have difficulties meeting overall district water demands?**

? **Are there certain areas of the district that are always a problem?**

? **Do you regularly have late season shortages?**

? **Have you ever compared actual diversions and deliveries to estimated crop requirements?**

? **Have you estimated your overall system efficiency?**

Scheduling of Deliveries

Ideally, water is delivered only when it is needed. We are all accustomed to this concept and apply it regularly when we turn on the tap at the kitchen sink. Irrigation water supply systems are usually not pressurized like domestic systems, so matching deliveries and needs is a much more complicated proposition. When deliveries don't match needs, there is the potential for wasted water or unmet demand.

? **Do you run water continuously in canals and laterals?**

? **Do irrigators in your district have access to monitoring and scheduling services telling them when they need to irrigate?**

? **Do you use a rigid-schedule (rotation) or advance ordering (arranged) system for water deliveries?**

? **How far in advance do users need to place their orders? Can you fill orders on shorter notice?**

? **Do you have the ability to quickly check or shut down canals and laterals to avoid spills?**

Efficiency of Application

Irrigation water delivered to the farm must ultimately be delivered to the crop root zone. The challenge in water application is to deliver water to the root zone efficiently and uniformly over the entire field, without putting too much in some places and not enough in others. Application efficiency and uniformity are affected by many things, but most prominently by field characteristics, water application methods, and water management skill of the irrigator. Evidence of poor application efficiency includes dry patches or ponding on fields, excessive tailwater runoff, and irregular crop stress.

? **Are the farm fields in your district relatively flat or is the land sloping or hilly? Are sprinklers common in the hilly areas?**

? **Do soil types differ greatly from field to field? Within fields?**

? **Is there a lot of variability in the effectiveness of on-farm water use?**

? **Does the district provide demonstration projects or training workshops for irrigators?**

? **Does the district have programs to make improved water application equipment or technologies more accessible to irrigators?**

Control of Drainage and Tailwater

Tailwater is produced when irrigation water is applied to fields at rates and in amounts greater than can be infiltrated into the soil profile. Drainage may include both tailwater and seepage water from deep percolation through farm fields. This deep percolation occurs when more water is infiltrated than can be retained in the crop root zone. Sometimes excess water must be applied to leach salts from the soil, but the presence of significant amounts of drainage and tailwater is often viewed as evidence of over-application of irrigation water.

? **Has your district constructed drains to convey tailwater and seepage away from irrigated fields?**

? **Do you monitor flows in these drains or at other points on local streams to assess the quantities of tailwater and drainage return flow being produced?**

? **Do you collect tailwater and drainage flows in ponds?**

? **Do you monitor the water quality in drains and ponds?**

? **Are there ponds in locations where it is feasible to pump tailwater back into your district's distribution system?**

Water Transfer Needs and Opportunities

Water transfer arrangements can take many forms. They may be formal or informal, temporary or permanent, within the district or with outside users. The basic idea behind all of them, however, is to move water from users having more than they need to users having less than they need.

- ? **Is there a method within your district for irrigators to transfer their water shares or allocations to other irrigators?**

- ? **Can such transfers be made to non-irrigation uses within the district?**

- ? **Have non-irrigation or non-district water users inquired about the district's ability to supply them with water?**

- ? **Are there local water needs that could be met by the district if transfers were allowed?**

- ? **Is the transfer within the district, within or out of the basin?**

- ? **Are there state laws or policies that affect this transfer?**

Environmental Considerations

The development of western irrigated agriculture has had impacts on the environment and ecosystems of the region. Construction and operation of water storage and diversion projects, and their management to varying degrees, have generally modified and depleted natural flow regimes, created wetlands in areas where they did not exist naturally, and degraded water quality by adding sediments, salts, and chemical residues from fertilizers and pesticides.

- ? **Are there wetlands or critical habitats affected by water use in your district?**

- ? **Are there endangered species in source or receiving streams?**

- ? **Are drainage waters from your district highly saline?**

- **What constraints do these issues impose on your operations?**

- **How do your operations affect these environmental values?**

- **Are there ways district operations could be modified to improve conditions?**

Public Concerns

Irrigated agriculture is undergoing more and more scrutiny by municipalities, industry, environmental groups and the general public. This interest may pose both constraints and opportunities for irrigation districts.

- **Has your district been approached as a potential source of water?**

- **Is your district facing new environmental regulations?**

- **Is your water storage facility also a recreational facility?**

- **Is your water storage facility subject to relicensing?**

- **Are there downstream water users who depend on your district's return flows?**

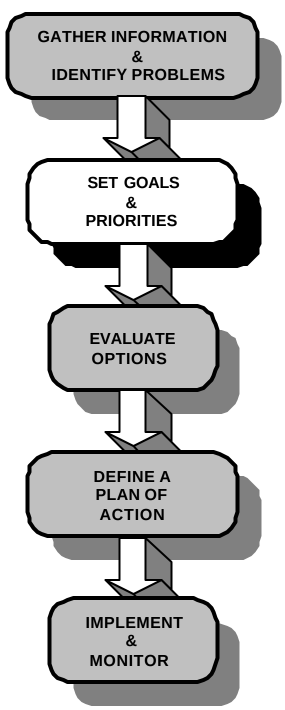
- **Are there upstream water users whose activities affect the amount and quality of your water source?**

PHASE 2 -- SETTING GOALS AND PRIORITIES

What Are Goals?

The objective of this second phase of the planning process is to define the goals of your water management planning effort. These goals will help you decide which water management measures make the most sense to implement. They will become the "yardsticks" by which you measure the success of your efforts. They need to state where you are going and why.

Goal-Setting



In addition to addressing specific problems within the district, some other areas where you should consider developing specific planning goals include the following:

- Providing leadership in solving regional water problems
- Improving coordination with neighboring water supply entities
- Enhancing the value of the water resource within and outside the district

There are some basic principles to follow when it comes to defining the goal statements that will drive your water management planning effort. These principles are derived from strategies for businesses but they are applicable to any directed activity. The principles are that goals should be:

Relevant

Goal statements need to address actual problems and opportunities faced by the district. The objective of the planning process is to identify and take appropriate actions to address potential water management problems and opportunities. Hopefully, the information-gathering and problem-definition activity of Phase 1 will have illustrated for you where some water management problems and opportunities exist. Your goals should build on these findings.

Consistent with Values

District goals will be more readily achieved if they are consistent with the values of district directors, staff, and irrigators. Their values are the basis of their motivation to support your management efforts.

Specific and Clearly Stated

Goals need to be expressed in clear terms and directed at specific activities. This principle is necessary in order to choose between management options and to gauge your progress. Vaguely stated goals will leave people uncertain about what they should do. If possible, goals should be stated in quantitative terms.

Written Down

It is essential to write down goal statements in order to communicate them consistently to others. It also makes a commitment that is not present when you just think about them. Use simple, concise, common language when writing goal statements.

Minimal in Number

Having too many goals will diffuse the resources your district can direct toward achieving any one of them. You don’t need to include all the possible goal statements that you think of -- some probably aren’t really important.

Challenging but Realistic

Motivated people generally respond well to challenges, but unrealistic goals will cause everyone involved to become frustrated and disillusioned. Goal statements should reflect the practical ability of your district to direct money and staff resources at the problem to be solved.

Visualized

Painting mental pictures of your goals is a very powerful technique. It helps you see them as more realistic and achievable. To the degree possible, you should try to share your vision with others on whom you will rely for help.

Long-term

Many water management improvements take time to develop and will not be realized immediately. Attitudes change slowly and voluntary adoption of new practices occurs incrementally. The district must maintain a leadership role over the long-haul to allow its efforts to bear fruit.

Achievement-oriented

If people don't see results from their efforts, they eventually lose interest. When developing goal statements, try to think of ways in which progress toward those goals might be recognized and publicized. This is especially important for goals that will take a long time to achieve.

Example Goal Statements

Here are a few example goal statements that reflect the principles stated above:

"Implement a water measurement improvement program by the end of 1998 to support future studies of district water use and management."

"Reduce seepage losses from system laterals to less than 5% of gross diversions by the year 2000."

"Develop, through improved water management, sufficient surplus supply capacity to provide 2,000 acre-feet of water annually for local industrial needs."

"Implement water pricing structures that will increase district revenues by $100,000 per year to support a revolving loan fund for on-farm water management improvements."

"Develop facilities and operating policies to support a 2-day advance water ordering system by the year 2010."

Setting Priorities

Chances are that you will identify several, perhaps many, goals for water management improvement. There may be more things you want to do than you have the resources to accomplish. If this is the case, you will have to decide which goals are the most important.

There are a variety of ways to set priorities among competing goals. Priorities might emphasize goals that are perceived to be important to the greatest number of people. Priorities might emphasize goals that have the least cost or the greatest financial return. Priorities might emphasize goals that enhance the physical performance of your supply system. Priorities might emphasize goals that are most in harmony with existing rules and regulations and with neighboring water management agencies. Priorities might emphasize goals that contribute more to improved water quality or habitat.

One way to assess the relative importance of problems and goals is to hold workshops or discussion groups with staff and with water users. After describing the water management problems you have identified and the possible goals you have defined, you can ask for a "straw vote." You might list all the possible goals or problems on large sheets of paper, hang them on the wall, and ask participants to "vote" on the five most important ones.

Your Board of Directors will obviously also be an important source of input for assigning priorities to the goals of your water management plan.

Given the importance of good information to good decision-making, it is probably safe to say that having good water measurement and accounting should be a top priority in every district. Without good water measurement it is difficult to quantify and evaluate water management problems and opportunities. It is also impossible to base accounting or pricing on actual water delivery unless those deliveries are measured. Accordingly, every district should consider adopting planning goals that include improved water measurement and accounting.

Ron, Sid, Iris and Wendell now have a pretty good idea that poor scheduling is the primary cause of at least some of the district problems. After considerable discussion, they determine that problems like seepage losses and insufficient deliveries to the lower end of the district are ultimately caused by inefficiencies in the system. The question now is how to proceed.

"Well, what are we trying to do here?" asks Ron, "I guess we should figure out what our goals are for this plan."

Sid thinks that charging for water use should be a goal. He argues that this will solve a lot of the equity problems and possibly provide funds for upgrading the district's delivery system.

"That's really a method, not a goal," reasons Wendell. "We should set a goal and then look at a couple of methods for achieving it."

Ron suggests that a goal might be to obtain more water from Spring Mountain Reservoir.

"We don't know if we need more water. In fact, it looks like we have enough water but we're using it at the wrong times," answers Iris.

"Yeah, you're right. A lot of the concerns raised at the meeting could really be boiled down to problems with water delivery service," says Ron. "If we limit our goal to getting more water or building more capacity, we might miss the point. We've made that mistake before."

"Okay, let's make improving delivery service a goal. **Then** we can look at raising rates to make things more fair," declares Sid.

"Should we have more than one goal?" asks Iris. "What about all that stuff about recreation at the reservoir and the instream flows on the South Fork? Can we come up with a goal to take a leadership role in the basin on environmental issues?"

"Yeah, I like that one. We shouldn't assume that we can just operate in isolation anymore. Or worse, wait until the public forces us to take action," agreed Ron.

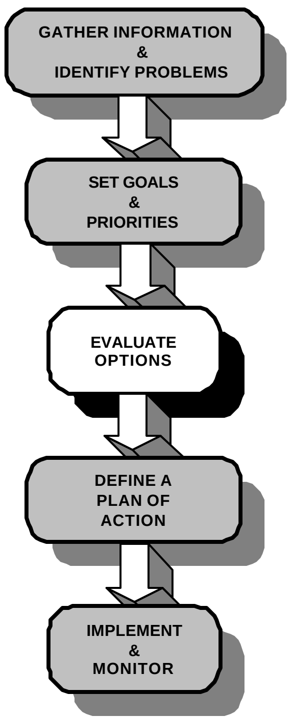
Sid laments that there are too many problems to try to solve at once and that they should limit their goals to solving just a few.

Ron, Wendell, Iris and Sid eventually agree that they should have just two goals for Springfield's water management plan:

- Improve water delivery service
- Take a leadership role in the South Fork basin on environmental issues

PHASE 3 -- EVALUATING WATER MANAGEMENT OPTIONS

Overview



This phase of planning activity involves identifying candidate measures for water management improvement and investigating how well each option might contribute to achieving the goals you defined in Phase 2. Usually this means that you will need to make rough assessments of costs, water savings, political acceptability, etc., of each of the measures being considered.

The evaluation process involves going back and forth between evaluation steps. You may decide, for example, that certain effects of a candidate measure are unacceptable but that the measure could be re-defined to avoid those effects. You would then go through the evaluation process for the modified measure. Hopefully, each time you go through this exercise you are getting more precise and confident in your evaluation.

Later in the planning process (in Phase 4) you will select from the most promising options to define an action plan. The basic objective of Phase 3 is to develop enough information about potential water management improvements to support these later decisions.

Identifying Candidate Water Management Measures

District management and staff are probably the people best qualified to identify potential water management improvements for the district. You may already have some ideas about water management improvements you would like to make. However, it is important to take a little time, think about the “big picture,” and involve some other people to make sure there aren’t other measures that would solve the important problems a little bit better.

The main focus in defining potential water management measures for consideration should be the goals you defined in Phase 2. If your goal statements are specific enough, they will almost "suggest" certain types of measures. Brainstorming in workshops and focus groups of staff members or irrigators is also a good way to generate ideas about potential water management improvements. Thinking of the possibilities is a very creative process. But you should always come back to your goal statements as the guiding principles.

In order to help you get the creative juices flowing, Section Three of this Guidebook contains descriptions and discussions of a variety of potential water management measures (there are many other potential measures). The general areas covered in these descriptions include:

- Improvements to water measurement and accounting
- Changes in water pricing and billing methods
- Education and training programs
- Operational and facility improvements to reduce water losses
- Improvements to water delivery scheduling
- Incentives for improving on-farm water management
- Development of contingency plans for shortage periods
- Ways to facilitate water transfers

You will probably want to refer to these descriptions and discussions frequently as you work through this phase (Phase 3) of the planning process.

Now that they have established the district's goals for the water management plan, Ron and the advisory committee meet to consider measures that might warrant investigation. They use Reclamation's *Guidebook for Preparing Agricultural Water Conservation Plans* for ideas on different water management measures.

"I really like this incentive pricing idea," announces Sid. "We could make a lot of progress toward improving efficiency if we could get folks to pay for the water they use. Remember, we decided that inefficiency was one of the basic causes of our problems. Besides, we might end up with some surplus revenues that we could use to pay for more flumes."

"We know you like that one Sid. Let's check it out, but let's spend some time looking at these other measures too, okay?" requests Ron.

Wendell suggests that canal lining might be a good measure to look at because it would solve the seepage problems and might help get more water to the end of the canal. "That would take care of our first goal of improving service. It should also reduce the drainage and return flow problems that our neighbors are giving us heat for and so would go a long way toward our environmental goal," he adds.

"Seepage is a problem but didn't the water budget point out that one of the root causes of our problems is that we're not delivering the water when the crops need it? How will lining the canal fix that problem?" asks Iris. "I think we should look at this irrigation scheduling measure. Maybe there's something we can do to get better alignment between our deliveries and demands."

"What if all the demands are concentrated at the same time? Even if we can time the delivery just right, we don't have the capacity to reach everyone simultaneously," worries Sid. "We'll have to invest in major canal construction."

"Well, let's check it out. Other districts have used irrigation scheduling haven't they? Let's see how they solved the capacity problems," says Ron.

"I think we can rule out these big-ticket items, like constructing regulatory storage, drilling wells and installing sprinklers. We just don't have that kind of money," says Sid.

"I agree. But some of the measures don't look that expensive. Look at this education one, for example. Maybe we can get some help from Reclamation or the NRCS in putting together a program to show farmers ways to be more efficient. An education program would also help us meet our second goal of providing environmental leadership in the basin," reasons Wendell.

Ultimately, Ron and the advisory committee resolve to investigate incentive pricing, canal lining, irrigation scheduling and education programs as candidate measures. They figure they need more data before they can make any final decisions so they contact Reclamation, NRCS and county extension staff to help them get rough ideas about costs and environmental effects. They also plan to contact districts that have implemented some of the measures to get information about legal issues that might arise.

Describing the Effects of Candidate Measures

Once you have identified some specific measures you think could help achieve your water management goals, the next step is to describe the effects of those measures. A wide variety of effects should be considered. Some of the more important ones include: cost to the district and to irrigators, changes in water flow and use patterns, and environmental effects. The discussions of specific measures in Section Three provide you with some ideas about how to estimate the effects of various types of water management measures.

Costs

Most water management improvements will have costs of some type. There may be material costs for equipment or construction. There may be labor costs for operation and maintenance. There may be financing costs if money is borrowed to pay for the improvements. There may be costs for more detailed studies or contract negotiations.

It also is important to consider who pays these costs. Some costs may be borne by the district, while some may be passed through to irrigators. The perspectives of both the district and irrigators should be considered when evaluating the costs of water management improvements.

Another important matter to be resolved is how the costs of improvements will be financed. Financing might be available from existing capital or maintenance funds. Some improvements might logically be paid for through user fees. Borrowing and levying taxes are other methods of financing available to some districts.

Each of the measures you are considering should be evaluated in terms of costs and financing requirements. Detailed cost estimates and financing strategies are probably not needed for the early stages of planning, but will likely be required later for some types of improvements.

Water Flow and Use Patterns

Improvements in water management will change water flow patterns in the district. These changes may take many forms, including reduced diversions from streams, reduced seepage from canals, more variable flows in laterals, less runoff from farm fields, increased deliveries to farm turnouts, etc. Changing some of these patterns may be the objective of the improvements, while changing others will be a side-effect of the improvements.

It is important to describe how flow patterns will change in the district as a result of water management improvements. You should attempt to make this description as detailed and quantitative as possible. Developing alternative district water budgets reflecting different potential improvements is a good way to estimate the amounts of water involved in these changes.

It will be particularly important to estimate changes in water use patterns that are related to district revenues. For example, if the district charges irrigators for the amounts of water delivered to them, your evaluation of management measures should estimate how farm deliveries would be changed.

Environment

Altering water flow and use patterns may have environmental effects. These effects are likely to be related to changes in overall diversions and changes in seepage and return flows. In general, water management improvements will result in more efficient water use and will reduce spills and return flows. The effects of this may vary from district to district. Since it is common for return flows to support wetlands and other habitats, these environmental features might be affected by changes in flow patterns.

There also may be changes in water quality. For example, if runoff from farm fields is reduced, there may be less sediment and nutrients in district return flows. Changes in flow patterns, wetlands, or water quality may also affect particular fish and wildlife species. Your Reclamation water conservation coordinator can provide additional assistance in this area.

Legal and Institutional Considerations

The implementation of water management and conservation measures must be done within the context of state water law and, for some districts, Reclamation law and contracts. Furthermore, some conservation measures may have environmental implications that require local, state, or federal permitting or mitigation activities. Water management measures that have been identified as having potential application in your district should be reviewed in light of these legal and institutional considerations before final decisions are made regarding their implementation. The advice of district counsel may be helpful in this regard.

Ron, Wendell, Iris and Sid have spent some time looking into the four measures they identified as candidates: incentive pricing, canal lining, irrigation scheduling and education programs. Wendell has collected rough estimates of costs per mile to line comparable canals in other irrigation districts. Sid has talked to other districts about incentive pricing and he has read Reclamation's *Incentive Pricing Handbook for Agricultural Water Districts* to get an idea of what would be involved in implementing a water pricing system. Iris has collected information on irrigation scheduling and Ron has visited with Reclamation to see what kinds of education programs have been put together by other districts.

One of the interesting pieces of information that has come out is that the county extension agent would be willing to give the district evapotranspiration and effective precipitation estimates each day if the district could figure out a good way to dispense the information to its farmers.

"Hey, maybe Larry would be willing to put it in that ad he runs each day in *The Springfield Herald*," exclaims Sid, whose brother-in-law Larry has a farm supply store. "It might get Larry's ad some more readers."

"Yeah," jokes Wendell, "maybe he'll take out that 20-year-old picture of himself and put in something useful. By the way, I discovered that canal lining costs are higher than I thought they'd be. We'd have to borrow a fair amount of money if we wanted to line the whole canal. Not to mention all the permits and regulations we'd have to deal with because the canal seepage has created wetlands. Does anyone know anything about NEPA compliance?"

"What I've learned is that irrigation scheduling can be really sophisticated or it can be fairly simple," reports Iris. "We could put in high-tech neutron soil probes, evaporation pans and computerize it all, or we could use Larry's ET and effective precipitation information. We could do this really cheaply at first and slowly build more sophistication into it, if folks think it's working."

"That sounds even more feasible than implementing water rates," remarks Sid. "What I've found is that we could start charging folks for water but we need a good way to measure how much they take. I had assumed that it would be fairly easy but the experience of this other district was that the farmers wouldn't accept water rates without credible measurement."

Ron adds, "Measuring deliveries is a pretty basic requirement for almost all of these solutions. We're way behind in that department. As far as education goes, I did find that we could put together some demonstration projects that could be moved from farm to farm and that we might be able to afford."

Ron and the advisory committee decide to do some more investigation and put together a presentation of their findings for the Board.

Displaying and Comparing Your Evaluations

You will need to obtain input from management, staff, irrigators, your Board of Directors, and others about the alternative water management measures you are considering. It will be important to do this before you decide to go ahead with specific measures in your action plan.

There may be quite a bit of information available about the alternatives you have evaluated. This can make it difficult to display the effects of the alternatives in a concise way. One approach that may be helpful is to use an evaluation matrix. A simple evaluation matrix format is shown in Figure 4.

To use this simple and familiar display method, first list the alternatives down the side and the effect categories across the top. You can make these lists and categories as simple or as complex as you want in order to get your points across. Then, in each "cell" of the matrix, put an indicator of the effect of each alternative. These indicators might be numerical estimates of costs or amounts of water, but they can also be simple terms like "good, neutral or bad," or "high, medium or low."

If more detail is needed to display the information, create one matrix for cost information, another for water savings, another for environmental effects, etc. This general approach is very flexible and can be easily adapted to suit your needs.

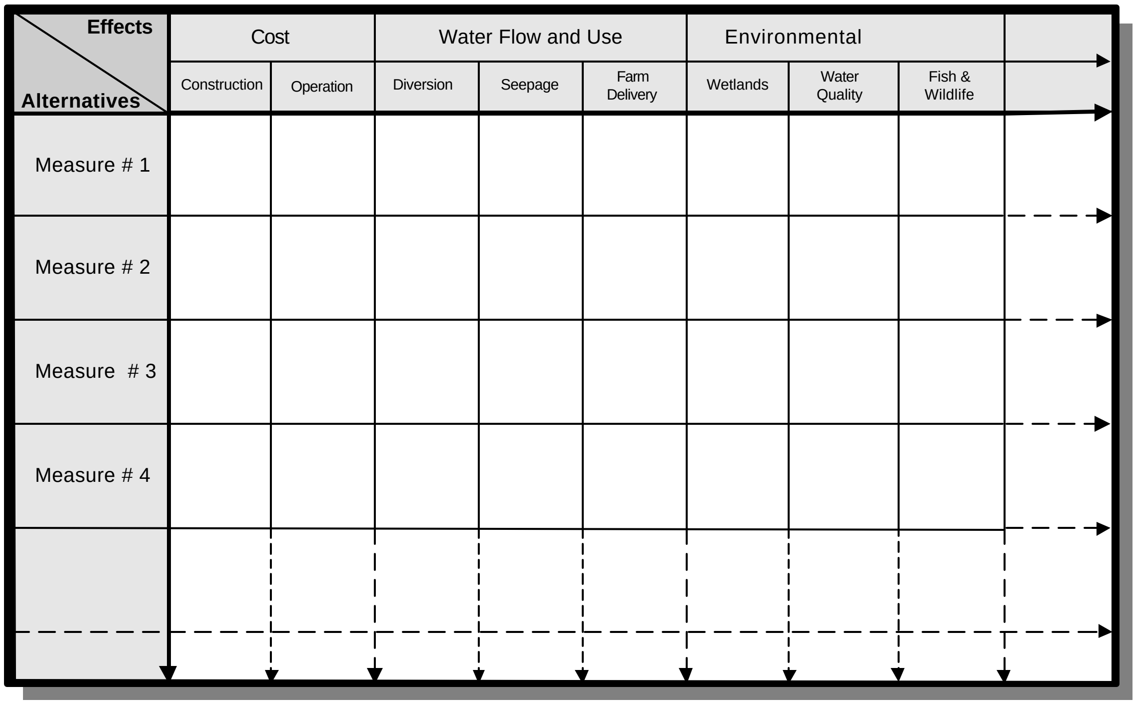
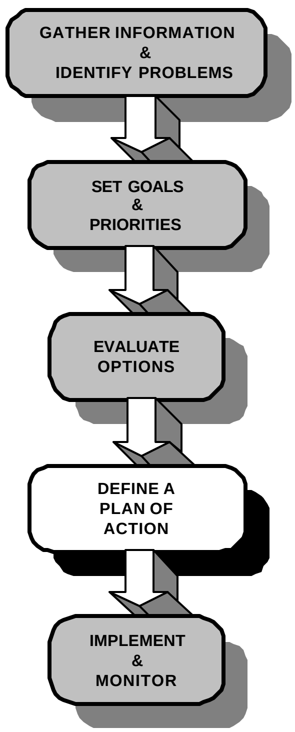


Figure 4: Evaluation Matrix

PHASE 4 -- DEFINE A PLAN OF ACTION

Overview



In this phase of the planning process you will decide which of the measures evaluated in Phase 3 you want to implement. While you may feel that you already know what you want to do, it is a good idea to take a little time to systematically review the information developed and be sure you are starting out with the most useful and effective management improvements.

You may ultimately want to combine various management improvement measures into *programs.* A program is simply a logically-related set of activities. You might, for example, define a water measurement improvement program that includes three measures: installation of meters or flumes on farm turnouts, more systematic observation of canal and lateral flows by ditch riders, and obtaining a database program for your personal computer to help store and analyze the data.

Your action plan will consist of one or more water management improvement programs. A schedule and budget to support the activities in each program should be defined.

Selecting Measures for Implementation

Comparing Measures with Goals

The most important indicator of whether a measure should be selected and incorporated into your action plan is how well that measure contributes to achieving the goals defined in Phase 2. Measures that do a better job of achieving your goals obviously are preferable to those that do a poorer job of achieving your goals.

If some of the goals are expressed in quantitative terms, you should be able to make a very precise comparison of measures relative to those goals. For example, if your goal is to reduce the amount of water lost to seepage from laterals by a certain percent, you can compare canal lining approaches on the basis of what percent seepage reduction each is expected to have.

Comparing Measures by Relative Cost

Another approach to deciding which measures to implement is to rank them on the basis of implementation cost. These costs should be expressed in comparable terms, such as annual or capitalized cost, and they should address both initial costs and ongoing maintenance costs. The timing of costs may be important if the district has other special financial requirements or situations.

Comparing Measures by Ease of Implementation

Clearly, some water management measures are easier to implement, politically, institutionally and technically, than others. Another approach to deciding which measures to implement is to rank them according to “ease of implementation” criteria. However, it is difficult to adopt this approach on anything other than a subjective basis. It may be more desirable to use subjective factors as “fatal flaw” screening criteria for elimination of alternatives that pose insurmountable political, institutional, or technical problems.

Comparing Measures on Benefit-Cost Basis

In this approach to evaluating alternative water management measures, the district would consider programs that have the highest benefits relative to costs. The ranking of programs by benefits and costs ensures that the district pursues those programs that are economically beneficial. The benefit-cost evaluation may be based on a variety of values. An evaluation based on saved water would involve two components:

- **Evaluating the benefit of saved water**: You should carefully analyze the value of water that your district saves through improved management and how that water can best be used. For example, your district might be able to resell the water to a municipality. The benefit of the saved water in this case would be the price that could be obtained per unit of water sold.

- **Evaluating the cost of saved water**: You should describe the cost of management improvements on a dollars-per-acre-foot basis. This is done by estimating the annual cost of the measure divided by the estimated amount of water saved annually. Measures can be ranked from lowest cost per acre-foot to highest cost per acre-foot.

Comparing Measures by Environmental Effects

Environmental effects are often the hidden costs and benefits of improved water management. Some measures will have more environmental consequences than others. A measure may have positive effects on drainage, erosion and water quality of return flows but may have detrimental effects on wetlands. A preliminary comparison of measures on the basis of environmental effects will help you anticipate what permits will be required, which government agencies will be involved, and what kind of support you will receive from the community.

Other General Considerations

Complementary and Conflicting Measures

Another thing to consider is the possibility that some water management measures may be complementary or conflicting. Complementary measures are measures that, when implemented together, would enhance the effectiveness of each other. Conflicting measures are those for which the successful implementation of one measure diminishes the potential effectiveness of another measure; such measures should *not* be considered for implementation together.

Water measurement and incentive-pricing are examples of complementary measures. Clearly, without good measurement of farm deliveries it would be impossible to know how much water an individual irrigator used during a given billing period. Accordingly, incentive pricing should not be considered unless development of adequate water measurement and accounting systems is considered along with it.

An example of conflicting measures would be encouraging installation of sprinklers and construction of on-farm reuse ponds. It is typical for the production of surface runoff (i.e., tailwater) to decline when sprinklers are substituted for surface application methods. Reuse ponds generally are designed to capture tailwater. Accordingly, if these two measures were being considered, it would be advisable to defer constructing the reuse ponds until the effects of sprinklers on tailwater production are well understood.

Conservation Investments by Others

The de-regulation of the electrical utilities industry in the United States holds some potentially interesting lessons for the water industry. One of these is the concept of "privatizing" investments in conservation. This concept might be applied to water conservation measures you think may be beyond your financial capabilities to adopt.

Under this concept, the district could define water management and conservation measures which require significant investment (canal lining, installation of sprinkler systems, etc.) and which are consistent with the district's overall internal goals, but which are beyond the financial reach of the district and its irrigators. Other entities within or outside the district would then be allowed to invest in one or more of these district-defined water conservation measures and would be entitled to some or all of the water saved, based on a satisfactory demonstration of actual savings achieved.

The recent agreement between the Metropolitan Water District of Southern California (MWD) and the Imperial Irrigation District (IID) is an example of this concept applied to water conservation. The MWD agreed to invest in substantial water conservation measures in the Imperial Valley (canal lining, 12-hour deliveries, drip systems, etc.) in return for access to the saved water for municipal purposes.

There may be water transfer aspects of this concept that need to be evaluated for it to be applicable west-wide. However, it emphasizes the need to examine all possible water management measures, irrespective of the district's financial ability to pay for them.

After presenting their findings to the Board of Directors, Ron and the advisory committee open the discussion for questions. The first question is about the district goals. Jim, the board chairman, says that he would like to expand the second district goal so that it doesn't just deal with environmental issues but that it covers water resource issues in general. Earl, the third board member, thinks the goals are already too broad and need to be much narrower to really be achievable.

"Let's set some objectives for each of the goals," says Ron, "Then we can have these broad goals and still have something measurable and achievable in the objectives."

After identifying four or five objectives for the goals, the discussion turns to the committee's suggestions for the plan. "Irrigation scheduling? The farmers are never going to go for that. How will they benefit?" asks Jim.

"Well, we'll definitely have to keep up our end of the deal. We'll have to make sure that they get the water they need, when they need it. The benefits should be higher yields, better quality crops and more cropping options, if we do this right," responds Ron.

Iris adds, "It should shift the bulk of the diversions to better coincide with the water demands, and give us more late-season water. Everyone will like that. Reclamation has agreed to work with us at Spring Mountain, to make sure we don't lose anything by keeping our water in the reservoir later."

"Huh, and that should make the boaters and fishermen quiet down, for a while anyway," grumbles Jim.

"Hey, be careful . . . a lot of our farmers are fishermen too. Including yours truly!" protests Earl.

The Board then turns to the concept of incentive pricing. "I don't see how we could start imposing water rates, Sid. It would be a good way to address the fairness issue but only if we can demonstrate to the farmers that we can adequately measure each farmer's use," says Earl. "Maybe after we've put in a few flumes and weirs we could revisit the idea."

"Then we could use the extra revenues to pay for this Cadillac canal-lining scheme you guys came up with," mutters Jim.

Sid agrees, "We thought it looked pretty expensive too."

"We've spent a fair amount of time looking at this and we recommend implementing an irrigation scheduling program, with the extension agent's help on ET estimates, and starting a couple of demonstration programs," says Ron. "We believe that these steps will take us a long way toward achieving our delivery service and basin leadership goals."

The Board decides to take the recommendations, slightly modified to include a long-range program of installing more flumes and weirs, to the irrigators and the community at another public meeting. They instruct Ron and the advisory committee to compile their investigations and recommendations into a draft water management plan for distribution before the meeting.

"And keep it short and simple!" snorts Jim.

Projecting Results of Selected Measures

Once you have decided which measures and programs will be part of your water management action plan, you will develop estimates of program water savings and other benefits, cost, and environmental consequences. You should be able to make these estimates from the information you developed in evaluating alternative measures.

Water Savings

The projected water savings of your plan might be derived by simply adding the projected savings of the measures that make up the plan, unless there are significant interactions between these measures. The water savings associated with some measures may be predicted fairly accurately. For example, concrete lining of distribution canals will predictably reduce losses to a few percent. The water savings associated with some other measures will be more difficult to predict, particularly if the measures rely on voluntary adoption of methods by individual irrigators. Some measures may not have water saving effects.

The timing of water savings should also be considered. For some measures, savings will be immediate once the measure is implemented, while for others the savings will only be realized over a period of time.

Cost

The cost of program implementation should be estimated in terms of initial costs and ongoing costs. The projected useful life of facilities or equipment should be considered here, since maintenance and replacement will be required over the long run.

By mapping these costs out over time you can create a cash-flow requirements table. A comparable cash-flow table should be developed for any revenues the district contemplates receiving in connection with the measures (e.g., from the sale or lease of water). These cost and revenue schedules will then facilitate development of net-annual-cost or net-capitalized-cost equivalents for budgeting purposes.

Environmental Consequences

You made some preliminary assessments of the environmental consequences of various plan elements in Phase 3 and made some relative comparisons of possible measures in Phase 4 of the planning process. Once you have decided on the elements that are to be part of your overall plan, you should prepare a written summary description of the probable environmental consequences of the overall plan.

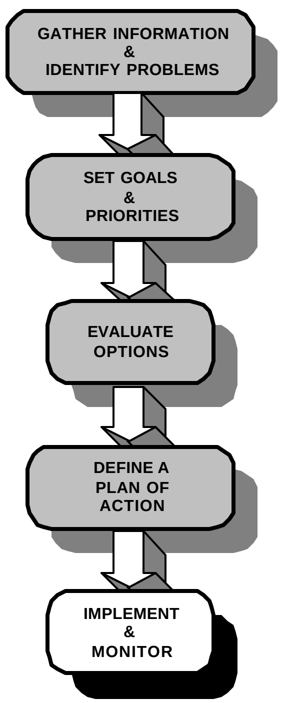
It is not expected that this description be a formal environmental assessment or impact statement, or a substitute for such documents. It should simply alert readers to the generally anticipated effects of the selected program of conservation measures. Specific benefits or impacts of consequence, as well as areas of uncertainty, should be highlighted. You may also wish to contact your local Reclamation Water Conservation Coordinator for further assistance.

PHASE 5 -- IMPLEMENTATION AND MONITORING

Implementation Schedules and Budgets

In order to make your water management plan a reality, you need to define the sequence of activities and then allocate the necessary funds to support those activities.

Schedule



The implementation schedule for your plan should reflect the time required to develop the various measures included in the plan. Certain changes may need to be presented to users as proposals first, allowing for some educational time before implementing actual changes. There also may be time required to develop necessary information and control systems and for district staff training.

Measures involving equipment acquisition or construction will almost certainly require more detailed feasibility study than they have been given in this management plan. This study would then be followed by preliminary and final design and preparation of construction plans. Permitting and environmental compliance may also be required before actual construction can begin.

Budget

The district budget for implementing the management plan will be based on the cash-flow requirements of the plan and the net-capitalized or net-annual cost of the plan. Depending on the contents of the plan, it may be possible to allocate funds from existing revenue streams for plan implementation.

If additional revenues are needed, the budgeting process will be dependent on the potential sources of that revenue. Some possibilities are increases in water service charges or water rates, increases in mill levies, and issuance of revenue or general-obligation bonds. It is possible that revenues from some of these sources will not develop immediately; if so, the plan implementation schedule will need to reflect the time required for this revenue development.

Staffing

Some aspects of the management plan may require additional effort by district staff. The plan should describe how duties would be assigned or how additional staff would be recruited and supported.

Monitoring The Plan

An important part of your water management plan is identifying and quantifying the water savings and other effects it achieves. This should take the form of an ongoing monitoring program because the effects of some measures will not be immediately evident.

It will typically not be possible to measure these effects directly. Water savings may be evident in reductions in diversions, farm deliveries, spills, drain flows, etc. These quantities have substantial natural variation from year to year, and you may need to accumulate several years of data in order to determine whether there has been a significant change. The parameters you originally examined in constructing your district water budget are the same ones you need to monitor to identify water savings. Monitoring effects may involve installation of measuring devices, better observation of existing measurements, more frequent spot checks, etc.

Your water management and conservation plan will not be complete without a description of the approach you intend to take to monitor its success.

The draft water management plan was generally well-received by the district irrigators. They liked the idea of more control over when they received water but were somewhat skeptical about the demonstration programs. They insisted that the demonstration programs be relevant and affordable, perhaps including some surge valves or gated pipe.

Comments from the public were favorable, especially those from representatives of the downstream municipality. They were especially encouraged by the district's commitment to an irrigation scheduling program. They had been considering upgrading their water treatment plant because drainage and return flows from the district were of such poor quality. Recreational users of the reservoir also had positive remarks and offered to work with the district to see what more could be done to maintain levels at the reservoir.

These comments and suggestions were incorporated into the water management plan, and an implementation schedule was developed. The schedule assumed that the easiest steps would be made first, so that any design or permit applications for the more complicated improvements could move ahead at the same time.

Iris called around for bids on the demonstration hardware and the flumes. Ron worked out the details between the newspaper, Larry and the county extension agent to get ET rates and effective precipitation information published each day. Wendell put together a procedure for getting feedback from the farmers.

Ron worked with Reclamation to refine the ordering process so that he could tailor deliveries to irrigation requirements. He contacted the farmers frequently over the first season, to see if the system was working. As soon as the flumes were installed, Ron started keeping records and began refining the water budget to better understand the district's losses and spills. He periodically compared this new data to the district's stated goals and objectives to see if they were on track.

Then one day he got a call from the Riverdale Irrigation District, just downstream of Springfield. They had heard that Springfield had put together a water management plan and wanted to know more abou

Section Three -- Potential Water Management Measures

This section of the Guidebook will help you evaluate potential water management improvements that might be applicable to your district. It will:

- ☞ Describe a variety of types of water management problems and measures
- ☞ Ask you questions about how these problems and measures are relevant to you
- ☞ Help you think of water management measures that best fit your situation

FUNDAMENTAL WATER MANAGEMENT MEASURES

Reclamation has identified four fundamental water management measures that should be considered in any water management program. They are:

1. Adequate Water Measurement & Accounting
2. Water Pricing Structure that Encourages Efficiency
3. Information & Education Services for Water Users
4. Designation of a Water Conservation Coordinator

Water Measurement and Accounting Systems

Effective water measurement and accounting is necessary for developing a sound water management program. A district's measurement and accounting systems should be capable of tracking the amount of water delivered to individual water users. These systems are effective water management tools because they help inform both the water user and the district about the quantity, timing, and location of water use.

From the district's perspective, water measurement will help with:

- Assembling information needed for a detailed water budget
- Identifying areas where additional efficiency can be achieved
- Implementing a billing system based on deliveries

At the farm level, water measurement will help with application of the proper amount of water to meet crop requirements and therefore may help to:

- Reduce erosion

- Reduce fertilizer leaching

- Reduce drainage problems

An effective water measurement and accounting system should accommodate some form of volumetric pricing and billing for individual users. The “ideal” water measurement system has flow measurements at all points in the diversion, conveyance and delivery system where flow division takes place, including farm turnouts and tailwater, drainage, and system spill locations. The actual number of flow monitoring stations required would depend on the size and complexity of the conveyance system. Where physical measurement capability at each agricultural turnout is determined to be infeasible, approaches can still be developed to provide individual user accountability and billing based on “blocks” or groups of users.

The ideal system would provide data on a real-time basis through use of automatic recording and data transmission devices. A comprehensive measurement program provides all the delivery information needed to develop a detailed system-wide water budget.

To determine where measurement is most needed the following questions should be considered:

? **Do you know amounts of water diverted into the system, in terms of flow rates, volumes, timing, and location?**

? **Do you know how much water was conveyed down major canals and laterals and turned out at individual farms?**

? **Do you know the amounts, timing, and location of system spills?**

? **Do you know the amounts, timing, and location of tailwater either leaving or returning to the system?**

There are a variety of methods for measuring flows in canals, laterals, and drainageways, and measuring on-farm deliveries. Many of these techniques are discussed in detail in Reclamation's *Water Measurement Manual* and supporting documents.

Water use accounting systems will vary between districts, depending on the complexity of the district's conveyance system and the amount of water measurement data available. For example, in some districts a simple ledger sheet might be used to track deliveries to a relatively small number of individual users or down a few canals or laterals. Other districts may use commercially available computer software or custom software developed to track deliveries through a complex system.

The appropriate accounting system must be determined at the district level, but in general, more detail is better. At a minimum, the accounting system should allow for tracking of water deliveries to individual users in order to accommodate a billing system based on deliveries.

Water Pricing Structure

To encourage efficient water use, a district's pricing and billing procedures should be based, at least in part, on the quantity of water delivered. Quantity-based charges can be incorporated into various existing pricing structures to provide some degree of economic incentive for efficient water use. Fairness in water billing is an additional benefit of quantity-based pricing structures.

Disincentives to efficient water use include situations where the unit price of water declines as the volume of water used increases (declining block structure) or where a fixed charge per acre of irrigated land is assessed regardless of the quantity of water used. Both of these examples can lead to excessive water use. By contrast, pricing structures such as increasing block rates or fixed rates provide an economic incentive for more efficient use. Figure 5 depicts some different types of water pricing structures.

When evaluating water pricing structures, it is important to consider potential effects on revenues generated through water sales. Under the new pricing system, will there be sufficient revenues to cover district operating costs? Will modifications to the pricing structure result in supplemental revenues that could be used to develop more improvements?

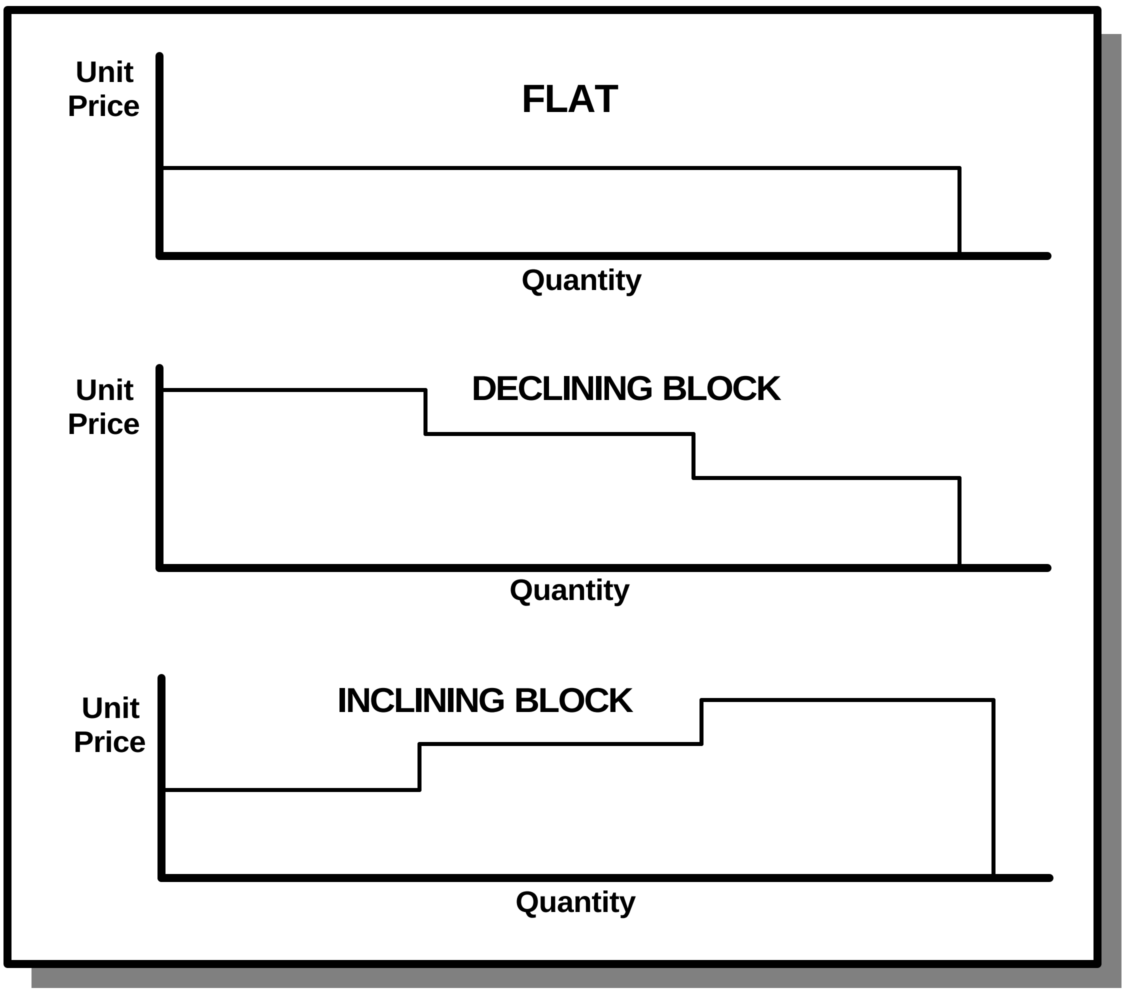


Figure 5: Types of Water Pricing Structures

Districts can encourage efficient water use by increasing the unit price of water as deliveries increase. With incentive pricing, a base price per unit of water is charged for all water deliveries up to a certain amount, or block.

Water use in excess of this block is then charged at a higher unit price. One or more pricing levels (or “tiers”) may exist within a pricing structure. The specific design of these structures will depend on individual district objectives.

The demand for water within an irrigation district is based on crop production and planning decisions made at the farm level. It also depends on crop selection, irrigation technique and land characteristics. The change in water demand in response to a change in water price is termed “demand elasticity.” Factors affecting demand elasticity include:

- Crop values
- Crop tolerance to water shortages
- Ability to change crops
- Ability to change irrigation methods
- Availability of alternative water sources

Typically, changes in water prices lead to only small changes in the quantity of water demanded. Therefore, the water supply and demand relationship is fairly “inelastic.” Water demand, price elasticity, and potential changes in district revenues resulting from price changes are important considerations in evaluating the use of incentive pricing as a water management measure.

Incentive pricing programs may be structured to optimize conjunctive use. For instance, a program may be designed to encourage surface water deliveries and groundwater recharge in wet years by lowering the price to the grower. In dry years the surface water price can be increased to encourage increased groundwater extractions.

Incentive pricing has successfully been implemented in California’s Broadview Water District. The purpose of this structure is to motivate growers to improve the efficiencies of their on-farm irrigation operations and to reduce the quantity of drainage water. The district’s increasing block rate pricing structure has two components, crop-specific price levels and field-level accounting of water deliveries. Crop-specific price levels are required because the volume of drain water generated from water application varies from crop to crop. Crops with higher ET rates are permitted to receive more irrigation water before reaching the higher price level. Without these concessions, growers could be limited in the kinds of crops they plant.

Field-level accounting of water deliveries encourages the growers to carefully monitor their irrigation supplies.

Incentive pricing may be an appropriate water management measure if the district's existing pricing structure is based on a fixed rate or if water charges are not linked to the amount of water delivered. To evaluate incentive pricing and other rate structures for your district, refer to the information and methods presented in Reclamation's *Incentive Pricing Handbook for Agricultural Water Districts.*

Educational Programs

An important component of any water management program is providing information to irrigators about efficient water use and water management services available through the district or other organizations. Educational programs can be effective because many water users are unaware of potential benefits from improvements in water use efficiency. Examples of educational programs include irrigation system improvement programs, on-farm irrigation scheduling programs, real-time agricultural evapotranspiration (ET) information, school and community educational programs, and technical and financial assistance programs. Information on the following topics could be made available to irrigators:

- Costs and potential water savings of water management measures

- Best management practices for soil and water conservation
- Irrigation method efficiencies
- Soil characteristics
- Day-to-day crop water requirements
- Actual on-farm water use from delivery records
- Actual district-wide water use and efficiencies

There are a variety of ways the district could convey this information to its water users. For example, a district could sponsor workshops covering topics such as weather, crop ET, soil moisture holding capacity, crop characteristics, and the role these factors play in irrigation scheduling and water use planning. Educational workshops also can serve the district by providing a forum for irrigators to exchange ideas and experience. It might be appropriate to provide basic wise water use information to the general public residing within the district.

Educational programs could include written publications, dial-in telephone services, or monthly water bills that provide water use data. Various local, state, and federal agencies provide technical assistance for agricultural activities. Districts should take advantage of these resources when developing their own programs.

Demonstration projects are another useful technique for educating water users. In these projects, specific measures are implemented in a controlled setting to allow precise determination of the effects. The results from monitoring demonstration projects are then presented to district water users, along with cost and implementation information.

Designating a Water Conservation Coordinator

Designating a district water conservation coordinator serves two primary functions: it allows the district to assign water conservation responsibilities and it provides a focal point through which all district water users and staff can consult. Responsibilities of a water conservation coordinator may include:

- Developing education and training programs
- Distributing data on soils, climate and crop water requirements
- Providing technical assistance on irrigation techniques
- Developing demonstration projects
- Assisting with irrigation scheduling

Reclamation and other agencies provide formal training in water conservation. Such resources allow conservation coordinators to keep up-to-date with conservation programs, services, and technological developments.

INSTITUTIONAL WATER MANAGEMENT MEASURES

This section discusses water management measures which might be implemented through institutional changes, that is, by changing rules and policies. These measures include:

1. Water Shortage Contingency Planning
2. On-farm Conservation Incentives
3. Water Transfers
4. Land Management

Water Shortage Contingency Plan

Drought mitigation may most effectively be accomplished through a combination of water development, water conservation programs and a drought preparedness or contingency plan. The basic objectives of a plan would include:

- Hydrologic forecasting to predict water supply
- Definition of water allocation procedures to be used during drought periods
- Identification of methods to increase reliability and use efficiency of existing water supplies
- Identification of alternative or supplemental water supplies

Hydrologic forecasting to predict water availability can provide farmers with information that will help them prepare for a drought. For example, given a forecast, farmers can choose to irrigate less land or grow crops that require less water. Forecasting also will help the district assess the need for temporary operational changes or supplemental water supplies.

Water allocation procedures used during normal hydrologic conditions may not be appropriate during times of drought. For example, conveyance and delivery systems may not be designed for precisely targeted deliveries, or there may be inequities related to either location of farms or types of crops grown. Water rationing techniques might include fixed allotments, percentage reductions, increased pricing, or restrictions on specific cropping. Defining allocation procedures before drought conditions begin will provide farmers with fairly certain information as to what they can expect in terms of water deliveries and will allow them to plan accordingly.

An important component of a water shortage contingency plan is the identification of alternative or supplemental water sources to use in emergency situations. The plan should define "triggers" that would initiate use of these alternative sources. It should also estimate the amount and timing of supplies expected from these sources. Potential alternative sources or techniques that might be used to supplement a district's water supply during drought periods include:

- Interruptible supplies (temporary transfers or dry-year options)
- Intra-district transfers
- Exchange arrangements
- Water banks
- Storage hedging, carryover storage and conservation storage
- Integrated operations with other water suppliers

If your district already has a plan, it may be necessary to review and update the plan to reflect changes in system operation, farming practices, forecasting technology, or potential alternative water supplies. Some questions to consider when establishing, developing, or updating a water shortage contingency plan include:

? **Does your district have a water shortage contingency plan and is it up-to-date in terms of operating procedures, farming activities, water allocation schemes and forecasting methods?**

? **Has a water shortage contingency plan ever been implemented due to drought conditions and if so, how severe was the drought? How well did the plan work?**

? **Are water users in the district aware of existing drought contingency policies and water allocation procedures during drought periods?**

On-farm Conservation Incentives

For some growers, the ability to implement efficient on-farm management practices and install modern water application equipment is hampered by the lack of capital. On-farm water management measures might include ditch lining, development of water reuse systems, installation of surge valves and gated pipes, sprinkler systems, field leveling, and soil treatments. Farmers may be willing to improve their irrigation efficiencies if long-term financing or other assistance is available from the district or other sources. Programs to provide incentives for on-farm water management may include financing incentives, in-kind services, and educational programs.

Some financial incentives which may be made available by the district include:

- Tax incentives for adopting certain water management measures
- Low interest equipment loans and leases
- Equipment purchase subsidies
- Water charge discounts or rebates for efficient water use

An incentive program may also consist of in-kind services to water users. For example, a district might establish a service to install on-farm soil moisture monitoring devices or provide climatic and crop water requirement data on a site specific basis. Such in-kind services may also be a part of efforts to improve district-wide irrigation scheduling.

Demonstration projects and educational programs may act as water management incentives by making farmers aware of different measures and the potential benefits of their use. For example, districts might set up projects to demonstrate the effectiveness of using gated pipes and automatic surge valve controls to eliminate the time-consuming process of manually adjusting irrigation settings.

In developing on-farm program incentives, the primary challenge faced by a district will be that of achieving good participation by water users. Financing opportunities, in-kind services, and educational programs may all be required to develop this participation.

For many districts, improvements in on-farm water use efficiencies offer the best opportunity for improving overall district water use efficiencies. Therefore, on-farm program incentives will be an important water management measure for almost all districts.

Water Transfers

Water transfers generally try to move water from areas of surplus to areas of shortage. They may be an effective technique for meeting water demands and for managing the impacts of drought. The objective of the mechanisms discussed here is to facilitate voluntary transfers that do not unreasonably affect the district, the environment, or third parties.

Water transfers can take many different forms and can serve a number of different purposes in the planning and operation of a district's irrigation system. The specific objectives of the district, in addition to certain legal or institutional constraints, will dictate which type of transfer mechanism is most appropriate. Types of transfers include:

- Permanent transfers
- Contingent transfers / dry year options
- Tradeable shares or allotments
- Water banking
- Transfers of reclaimed, conserved or surplus water
- Water wheeling or other exchanges

A permanent transfer involves the acquisition and change in ownership of water rights or allotments. Permanent transfers might be arranged on an intra-district basis or between the district and water users outside of the district.

Contingent transfers and dry-year options are temporary arrangements. These transfers often define an "interruptible supply" that may periodically be used under certain conditions such as drought.

The simplest type of water transfer mechanism that a district might implement would be to set up a system of tradeable water shares. For example, the district might define shares or units representing fixed water allocations that could be bought and sold by irrigators within the district. In districts that are characterized by a wide range of crop values, such intra-district transfers would likely result in water allocations that maximize overall district economic benefit.

Water banking refers to arrangements whereby excess or unneeded water may be consigned to a "bank" by one user (or district). The water can then be purchased by another user who needs more. Water banks have been used to facilitate transfers to users outside irrigation districts and for uses other than irrigation.

Wheeling arrangements typically refer to cooperative agreements aimed at improving the storage or conveyance performance of a system. For example, an arrangement may call for water belonging to one district to be carried in a common canal with water from another district, thereby reducing overall canal seepage and evaporative losses. Losses might then be shared proportionally by both districts.

Transfers may also involve the right to use water that is made available by reclamation or reduction in water demands, or through successful water conservation efforts. The right to use reclaimed or conserved water is a legal issue that will vary by state. In some areas, such water may simply revert back to the original source and become available to other users. In other areas, it may be possible for the entity responsible for the water savings to sell or lease the water to other users. Some districts have been able to finance conservation programs through sale of the rights to conserved water.

Some of the questions you should consider in evaluating the relevance of water transfer measures to your district include:

? **Do state laws or district bylaws prohibit or encumber water transfers through specific restrictions or limits on transfers?**

? **Would transfers involve federal water rights, storage or conveyance facilities, or affect existing federal project operations, and would a transfer be consistent with existing contractual agreements?**

? **Are there unmet demands within the district or in the general area that might be served by a water transfer?**

? **Are the district conveyance facilities sized and located favorably with respect to potential transfer opportunities?**

Land Management

Land retirement, fallowing, or conversion to dryland farming may be an appropriate water management measure if needed improvements in water use efficiency cannot be achieved on specific farms or fields. Land retirement refers to the permanent removal of irrigation supplies, while fallowing refers to a temporary removal of irrigation supplies. Conversion to dryland farming may be appropriate if local soils and climate conditions support production of alternative crops.

Lands within most irrigation districts have been classified by Reclamation according to their irrigability and potential productivity. The classification process considers soil characteristics, topography, drainage, water quality, economics of production and land development and climate. Class 1 lands are considered to have the most production potential and to be most easily irrigated within the project area. Higher class numbers are assigned to lands expected to be less productive and less efficiently irrigated or relatively expensive to develop for irrigation.

Land classifications often date to the time of original establishment of an irrigation district and may be outdated due to improvements in irrigation technologies and farming practices. For example, the availability of land-leveling techniques means that significant improvements could be made to the irrigability of some lands. It is important to consider if existing classifications are still accurate. First-hand knowledge of field situations is often the best information source for district-wide planning.

The decision to retire land, fallow it, or convert to dryland farming may depend on many factors in addition to the lands' irrigability. These factors would include economic implications for both the farmers and the district and potential alternative uses of the lands. With regard to alternative land uses, increased demand for recreational facilities has provided an opportunity for conversion of some agricultural lands in Arizona to parks, golf courses, and shooting ranges. Alternative uses may be permanent in nature or may be such that re-establishment of agricultural practices is possible at some point in the future. The permanence of the change will play an important factor in considering the economic viability of land management changes.

Once certain lands have been identified as potential candidates for land use changes, the district must encourage land owners to accept and make the changes. Some incentives include:

- Outright purchase of low irrigability lands
- Modification of district boundaries to exclude low irrigability lands
- Tax incentives for ceasing to irrigate certain lands
- Payment in-kind programs
- Water pricing structures favorable to higher quality lands
- Demonstration projects and education programs on dryland farming

Questions to help determine if this measure is relevant to your district include:

? **Are there lands within your district that would be candidates for retirement or fallowing because of poor irrigability or productivity?**

? **Does your district have legal authority to acquire low irrigability lands through outright purchase or condemnation?**

? **Does your district have the legal authority to provide tax incentives for farming of lands with high irrigability?**

? **Does your district have the legal authority or contractual flexibility to structure water prices based on irrigability of lands?**

OPERATIONAL WATER MANAGEMENT MEASURES

This section discusses water management measures which would involve changes in system operations. These measures include:

1. Improved Operating Procedures
2. Improved Distribution Control
3. System-wide Irrigation Scheduling
4. On-farm Irrigation Scheduling
5. Conjunctive Use of Surface and Groundwater

Improved Operating Procedures

Changes to a district’s operating procedures may provide for increased delivery and storage flexibility. Some operating procedures which might be candidates for improvement are:

- Water ordering and delivery
- Canal/lateral operating practices
- Reservoir operations
- Integrated system operation

Methods for scheduling water deliveries to individual farms vary depending on characteristics of the available water supply, diversion and conveyance facilities, and irrigation water demands. The advantages and disadvantages of different water ordering and delivery scheduling methods must be considered from the perspectives of both the district and its water users. For example, schedules based on a fixed amount and fixed frequency of delivery may require the least capital investment and operating cost to the district. However, they can result in a severe mismatch between supply and demand at the farm level. Delivering water on demand requires very active participation by the district in demand forecasting and control of delivery facilities, but will usually reduce waste and under-deliveries. In general, schedules that allow for the most flexibility in both timing and amounts of water delivery will be the most expensive to operate. The costs associated with increasing this flexibility must be balanced with district objectives and expected benefits.

Closely related to a district's scheduling system are canal and lateral operating procedures. Some districts must run canals full in order to serve certain laterals or farm turnouts. During periods of reduced demand, this practice may result in significant spills at the ends of the canals. To avoid these spills, the district might institute a policy whereby canal levels would be more actively checked and would fluctuate seasonally. This might require modifications to some turnouts or siphons, but it could also provide substantial water savings.

Reservoir operations are another area where modifications can be made to improve efficiency. For example, releases made only in response to irrigation demand may greatly reduce the probability that storage water releases will go unused on farms. A policy which allows for carryover of storage water allotments, rather than "use it or lose it" policies may reduce the tendency for irrigators to use late season water even when it's not needed by crops. Policies also might be adopted to allow dedication of carryover storage to a water banking system.

Integrating the operations of several districts can improve water use efficiencies while at the same time improving overall system yield. Integrated operations have been particularly successful in areas where storage or delivery facilities are shared. For example, studies of the Colorado-Big Thompson / Windy Gap projects in northern Colorado have shown that integrated operations can increase the reliability of both systems.

To evaluate the relevance of improved operating procedures for your district, consider the following questions:

- ? **Does your district have flexibility, in terms of physical limitations and legal and contractual obligations, to modify its current operating practices and procedures?**

- ? **Can your district adjust deliveries based on changes in demand?**

- ? **What is your district's policy concerning carryover of water allotments within and between irrigation seasons?**

- ? **Does your district allow water users to transfer portions of their allotments to other water users either inside or outside of the district?**

- ? **Are there opportunities to integrate operations of the district's facilities with the facilities of other irrigation systems in the area?**

Distribution Control

Distribution control refers to the ability of the district to control delivery rates and amounts of water. Of particular interest are the physical capacities of the system (diversion structures, canals and laterals), control mechanisms (gates, checks and weirs), and the ability of the district to operate these facilities in response to changes in water demands and hydrologic conditions. Limitations on physical features of the distribution system or difficulties responding to changes in hydrology and water demands may result in over-delivery to farm turnouts and system spills, or under-deliveries, water shortages, crop stress and lower crop yields.

Measures to improve distribution control may be categorized as either facility-related, measurement-related or communication-related. Facility-related improvements include installation of new structures or improvements to existing structures to more precisely manipulate flow rates and head levels (check dams, variable flow rate turnouts, automated controls). Regulatory storage and spill interceptor canals are two facility-related measures discussed in detail later in this section.

Improvements in flow measurement may be needed to help monitor and control water distribution. The use of a specific measuring technique will depend on hydraulic conditions and characteristics of the situation. Many measurement techniques may be used in conjunction with automatic recording and data transmission systems so that flow data may be available immediately and continuously at a central control point.

Timely information gathering, processing and dissemination to facilities operators is essential to efficient system control and to minimizing system waste. Operators must be kept informed of and be able to report changes in hydrologic conditions and diversion rates. Improving such communications may be as simple as buying cellular phones for ditch riders.

Questions to help you evaluate if this measure is relevant to your district include:

? **Is the district distribution system, or a portion of it, operated under pressurized water conditions?**

? **Is your district able to modify the amount of water it receives through its diversion facilities? Are there contractual or legal obligations to divert at a fixed rate or a fixed volume?**

? **Is your district able to modify flow rates in all parts of the distribution system in a timely manner to match localized demands?**

? **Does the district experience frequent and significant operational spills or experience canal flooding when demands drop?**

System-wide Irrigation Scheduling

System-wide irrigation scheduling attempts to schedule water deliveries to match irrigation requirements. System scheduling differs from on-farm scheduling in that, from a district perspective, the objective is to understand aggregated irrigation needs in district sub-areas, rather than on each individual farm. The district may then attempt to match deliveries to these sub-areas, subject to certain operating and distribution control constraints, as shown in Figure 6.

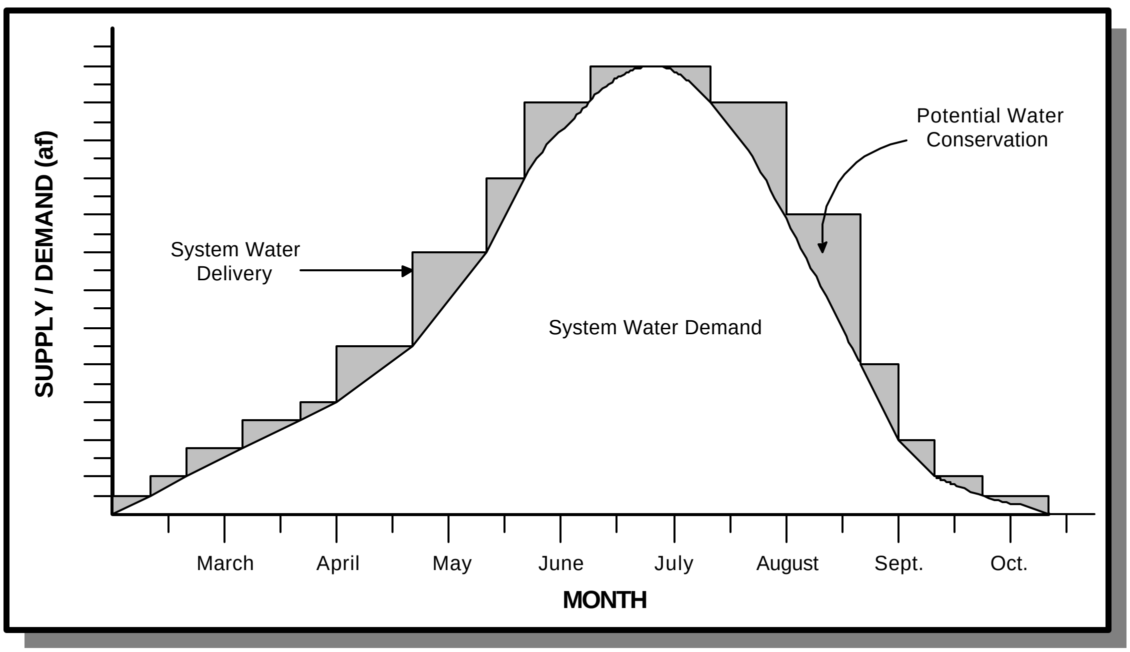


Figure 6: Water Conservation Through Improvements in System-wide Irrigation Scheduling

Much of the data needed for system scheduling is the same as for on-farm scheduling. In fact, one approach to system scheduling is to base it on actual water orders from farms. However, it may be more effective for the district to develop its own demand forecasts for specific crops and district sub-areas. Information required to develop irrigation demand forecasts includes:

- Types of crops grown
- Acreages of each type of crop grown
- Location of acreages (grouped into sub-areas by geographic location)
- Estimated ET for each crop type and sub-area
- Estimated soil moisture conditions within each sub-area
- Estimates of irrigation application efficiencies for each sub-area
- Information on groundwater and sub-surface return flows that may contribute to sub-irrigation

Information about cropping patterns and acreages should only need to be gathered once a year, though the acreage, types of crops and on-farm water application methods will likely change from year to year. ET rates and soil moisture conditions, on the other hand, will change dramatically throughout the irrigation season and up-to-date information will be needed on a real-time basis. Therefore, the greatest challenge in irrigation system scheduling may be the collection and processing of continuous climate and soil moisture data to develop estimates of crop water requirements.

Techniques for estimating crop water requirements include direct field observation and measurement, and theoretical calculation based on climatic conditions. The direct techniques include pan evaporation, visual inspection of plants, and representative plot lysimeters. Recently, advances have been made in the use of infrared sensing of crop moisture levels. Theoretical equations for estimating water requirements include the Blaney-Criddle, Penman-Monteith, and Jensen-Haise methods.

Monitoring soil moisture provides information on the amount of water held within the root zone of the soil that is available to meet crop needs. It may be measured by neutron probes, tensiometers, electronic resistance blocks, and by feel and appearance.

It may be possible to use one or a combination of these methods to estimate ET rates and soil moisture conditions. Because the objective of the district will be to forecast water needs for district sub-areas, data will not be necessary for each individual farm. Instead, data collection points should be located such that they provide information representative of the entire sub-area.

Processing information on climate and soil conditions in order to forecast irrigation needs may be facilitated by a computerized information management system (IMS). These systems have already been developed in some areas. The California Irrigation Management Information System (CIMIS), developed by the California Department of Natural Resources, uses an automated electronic weather station network to provide up-to-the-minute ET information. IMS's have also been developed that use soil moisture data collected by networks of neutron probe stations (rather than climate stations) to forecast irrigation requirements. These systems are usually developed for personal computers.

Irrigation application efficiencies may be estimated from application methods, characteristics of irrigated lands and soils, discussions with farmers and comparisons of calculated crop water requirements with historical farm deliveries. An understanding of the reliance on subirrigation in different sub-areas may be developed through discussions with individual farmers or through examination of the water budget.

The following questions should be considered to evaluate relevance of this measure to your district:

? **Do your water accounting records or comments from district water managers and individual farmers indicate a good match between supply and demand at a district-wide level?**

? **Is there a method by which farmers can place water orders with the district based on need (i.e., irrigation requirements)?**

? **Does your district support on-farm scheduling and is water requirement data available to, and understood by, farmers?**

? **Do system spills often result from major laterals or canals because of changes in on-farm demands?**

? **Will district distribution system facilities allow variable flows in different parts of the system without adversely affecting farmers' ability to take water through their turnouts?**

On-farm Irrigation Scheduling

When to irrigate and how much water to apply are the two basic questions each irrigator must answer during the irrigation season. The answers will change throughout the irrigation season and will depend on crop type, climate conditions, soil types, application efficiencies and previous water applications. Improving on-farm scheduling to better match actual crop needs, thereby reducing over-application of water, may be a very effective water management measure.

On-farm irrigation scheduling can be based on the following methods:

- Crop and soil appearance and feel
- Water availability (often a fixed frequency)
- Theoretical ET calculations
- Allowable soil moisture depletion

The method chosen is usually a function of crop type and sensitivity to the timing of water application, availability of data, time constraints of the irrigator, and system-wide water delivery flexibility.

Scientifically-based irrigation management considers soil characteristics, specifically the ability of soils to store irrigation water. The water holding capacity that is available to plants may be defined as the difference between the soil *field capacity* and the *wilting point*. The field capacity can be thought of as a full soil moisture reservoir, while the wilting point can be thought of as an empty one. Soil moisture holding characteristics vary by soil type. Characteristics are usually determined in a laboratory, although approximate holding capacities for various soil types are published.

The amount of water that is available to the plants is termed the *available capacity*. A common objective of irrigation scheduling is to maintain soil moisture above some minimum *refill point*, such as 50% of the available capacity, and to prevent soil moisture from decreasing to the wilting point, when crop stress occurs. This active soil moisture reservoir, between the field capacity and the refill point, is commonly referred to as the *allowable depletion*.

Figure 7 illustrates how these concepts apply to the scheduling of irrigations. At the beginning of the growing season, the root zone is assumed to be full (or soil moisture is at field capacity). ET from the crop steadily depletes the soil moisture over time. When the soil moisture level reaches the refill point, it is time to irrigate, and afterward irrigation soil moisture is again at field capacity. The *irrigation interval* is the time between subsequent irrigations.

The rates at which the soil moisture reservoir is depleted will depend on seasonally varying ET rates specific for each crop. Precipitation events will also affect soil moisture conditions and therefore the irrigation interval. For these reasons, real-time information on actual soil moisture conditions is essential for effective irrigation scheduling.

Irrigation scheduling using ET estimates and soil moisture data may offer excellent water management opportunities. Both of these methods are more quantitatively-based and allow a better estimate of true crop needs than simple visual inspection, and will almost certainly result in meeting crop needs more effectively than irrigating on a fixed frequency. However, the difficulty in using these methods is that information must be collected and made available continuously throughout the irrigation season.

Numerous examples of data collection and information distribution programs have shown these programs to be feasible, affordable, and to provide individual farmers with valuable information to assist them in on-farm scheduling. Often these programs involve cooperative data collection efforts between Reclamation, the NRCS, other agencies, and the farmers themselves. A variety of information distribution methods are possible including dial-in services, radio announcements, central literature postings, and communication with a water conservation coordinator.

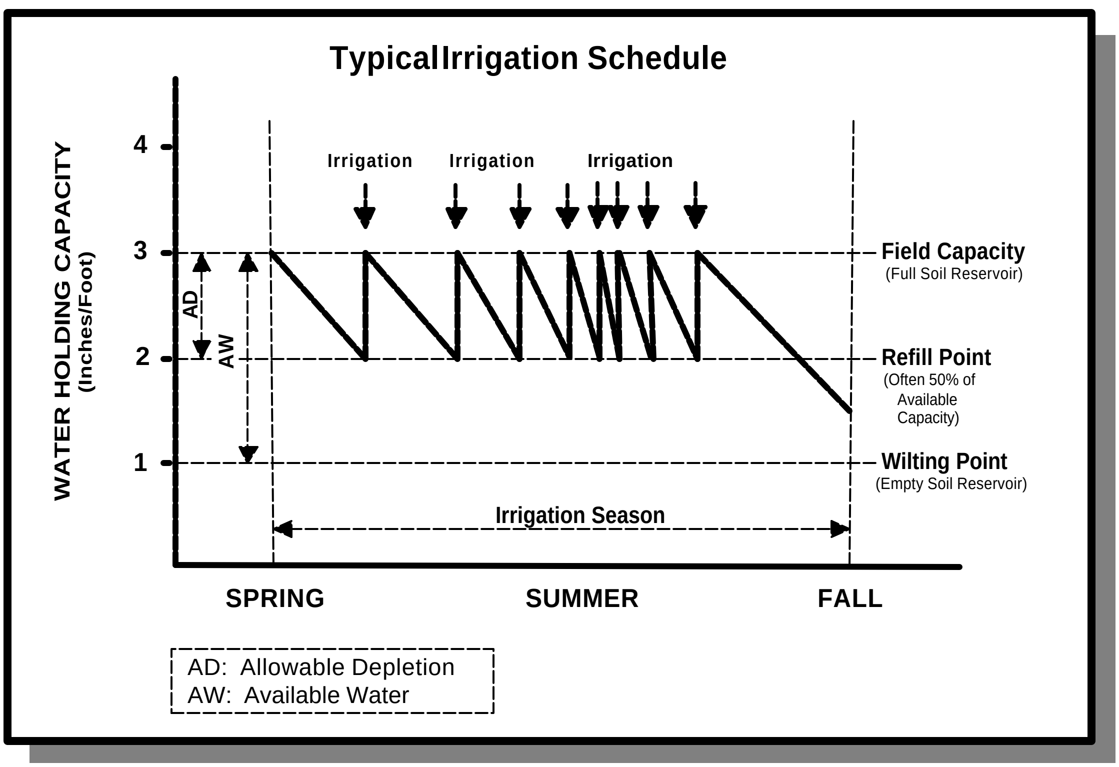


Figure 7: Irrigation Scheduling Based on Soil Moisture Status

Source: United States Department of Interior, Bureau of Reclamation, March 1995.

To evaluate the relevance of on-farm scheduling to your district, consider the following questions:

? **Do farmers have enough information about actual crop requirements to determine when to irrigate and how much to apply?**

? **Is the district system flexible enough to adequately meet the farmers' needs in terms of amount and timing of water deliveries?**

? **Based on the district's water budget, is there a reasonable match between water deliveries and crop water requirements on a district-wide basis?**

? **Is crop stress due to over- or under-irrigation frequent in the district?**

Conjunctive Use

Conjunctive use is the coordinated operation of surface water and groundwater resources to meet water requirements. Conjunctive use may provide an opportunity to increase the firm water supply to a district or to more efficiently use the existing supply. In the former case, groundwater is used during periods when surface water supplies are less than demands. Such a situation may or may not result in a net depletion of the groundwater resources, depending on how the aquifer is recharged.

When conjunctive use is used to better regulate supplies, surface water available in excess of demands is intentionally used to recharge the underlying aquifer. This is followed by aquifer pumping when the surface supply is less than demands. In this case, the underlying aquifer effectively becomes a regulatory storage vessel. Recharge systems include injection wells, spreading basins, sump areas, and recharge pits constructed in areas with high permeability. The feasibility of a groundwater pumping system will be a function of the local hydrogeology and specific water needs. A conjunctive use system may have automated controls to coordinate the groundwater component with flow conditions in the surface system and with water demands. A conjunctive use program may also be appropriate in situations where it is more efficient to use a water supply nearer to the actual demands, as shown in Figure 8.

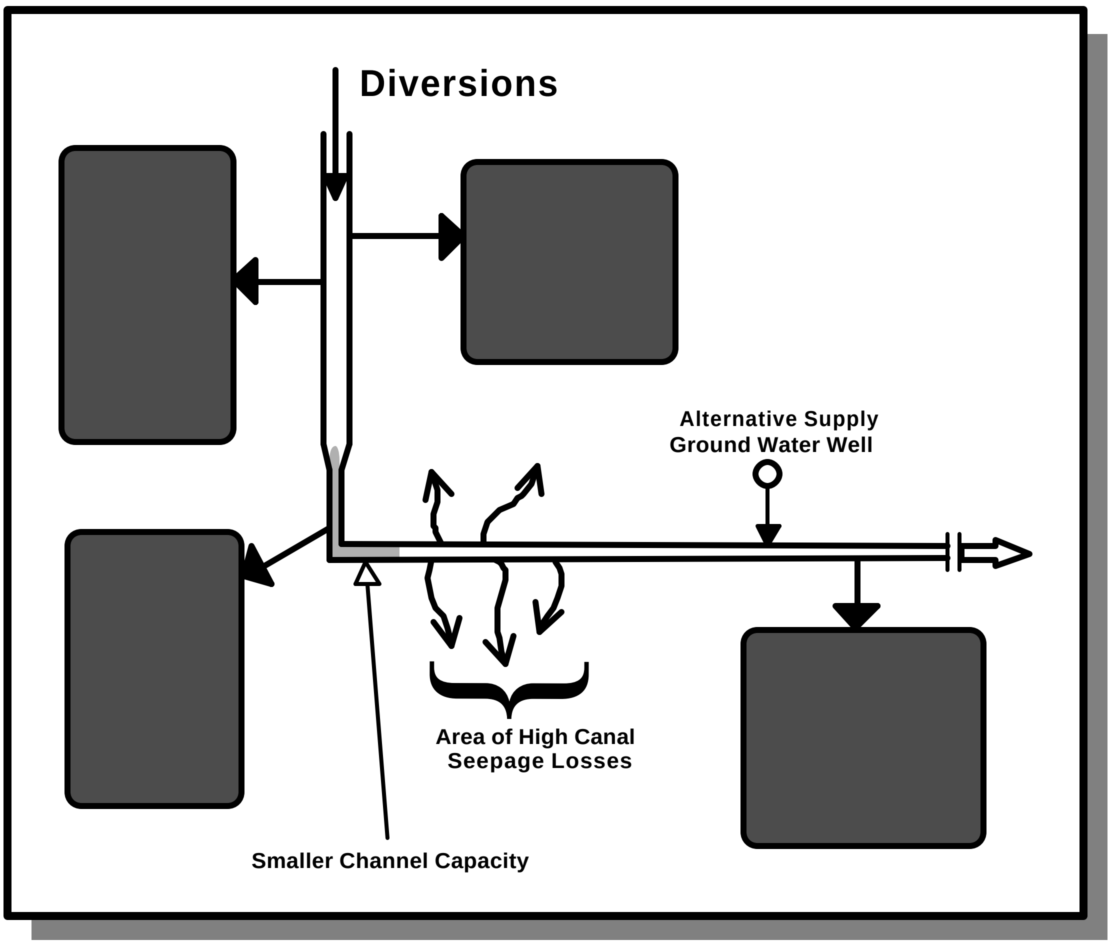


Figure 8: Conjunctive Use Program
Which Takes Advantage of a Nearby Ground Water Supply

There are potential consequences associated with groundwater pumping that should be considered by the district. Groundwater mining may occur from pumping in excess of recharge rates, resulting in higher pumping costs, reduced water availability and aquifer depletion.

Pumping may also affect nearby surface water rights if the surface supplies are hydrologically connected to the groundwater. Groundwater pumping may affect the yields of other groundwater wells and salt-water intrusion may be a consequence in coastal areas.

Questions to help you evaluate the relevance of this measure to your district include:

? **Is suitable groundwater physically and legally available in the district?**

? **Does the district experience periods of water shortages and are shortages due to limitations on diverted supply and/or distribution control?**

? **Do problems with system losses, distribution control and system scheduling make it difficult to deliver water to specific areas in the district which might be served by closer groundwater supplies?**

? **If regulatory or carryover storage would improve distribution control, could groundwater storage offer the same benefits?**

? **Is the geology of the aquifer and quality of the recharge water sufficient to make recharge and later use feasible?**

FACILITIES-RELATED WATER MANAGEMENT MEASURES

This section discusses some water management improvements achieved by constructing or modifying water delivery facilities. The topics include:

1. Construction of Regulatory Reservoirs
2. Lining of Canals and Reservoirs
3. Development of Water Reuse Systems

Construction of Regulatory Reservoirs

Distribution system regulatory reservoirs can play an important role in helping the district match water deliveries to crop requirements. This may be especially true in systems that schedule deliveries on a rotation or fixed frequency. Regulatory reservoirs allow farmers to use their allocations at their convenience, both in terms of time of irrigation and the amount of water used. In addition to increasing water delivery flexibility, regulatory reservoirs may be used to:

- Reduce overall system spills
- Capture storm water runoff
- Capture tailwater runoff potentially available for re-use
- Help control desired groundwater levels to facilitate subirrigation

Regulatory reservoirs should be strategically located in the district service area. Depending on the operational problems experienced, it may be most advantageous to locate a larger reservoir at the highest point in the system so that it may be used to regulate deliveries to all water users. If, on the other hand, distribution problems are more localized, a smaller reservoir constructed near the problem area might be in order.

The best indication of a need for additional regulation of water supply is a mismatch between water supply and demand. The demand for water may exceed supply because of a limitation in the available physical supply or because of bottlenecks in the conveyance facilities. The water supply may exceed demand at some times but be insufficient at others. In many systems, distribution control may be adequate overall but the speed at which a district can modulate supply to a particular area is inadequate to avoid shortages or system spills. Figure 9 shows a typical demand and supply relationship and the potential benefit in management flexibility and water conservation associated with regulatory storage.

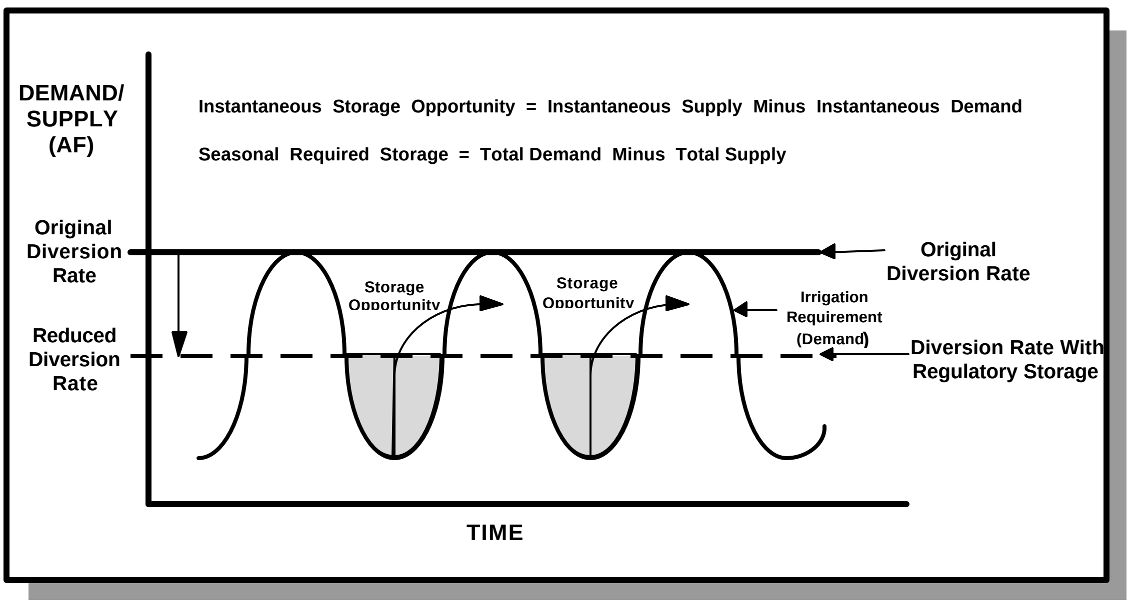


Figure 9: A Possible Demand and Supply Relationship and the Potential Benefit in Flexibility from Regulatory Storage

The following questions will help the district evaluate relevance of this measure:

? **Does your district obtain its water at a constant or variable rate? How well do the rates match water demand?**

? **Does your district already have regulatory reservoirs in its supply or distribution system that may be used to facilitate water delivery scheduling?**

? **Is there a mismatch between water delivery rates and irrigation water demand on either a district-wide basis or in specific sub-areas?**

? **Are there problems meeting demands in some areas of your district due to supply limitations or physical constraints of the conveyance facilities?**

? **Do limitations on response time by district water managers result in demand shortages or over-deliveries?**

Lining of Canals and Reservoirs

Canals, laterals and reservoirs may experience significant water losses due to seepage or evaporation. Installation of reservoir and canal linings or pipelines are effective methods to reduce these conveyance and storage losses. In addition to control of seepage and evaporation, lining and piping may provide the additional benefits of erosion control, reduced maintenance, increased safety and system pressurization (piping only).

Factors affecting seepage or evaporative losses from conveyance and reservoir systems include:

- Bottom soils
- Capillary forces and gravity

- Silt deposition from operation
- Water depth and surface area
- Wetted area
- Water velocity
- Depth to groundwater
- Ground slope

Losses due to seepage from unlined canals may range from 10% to more than 50%. Lining activities commonly reduce losses to less than 10%, although the expected amount of water savings will depend on site characteristics and the type of lining used. A similar reduction in seepage losses can be achieved through piping with the additional benefit of reducing evaporative losses and possibly pressurizing the system.

Significant seepage losses within the district may be indicated by the overall district water budget. Other general indications of seepage losses include phreatophyte growth adjacent to canals or reservoirs, water logging or ponding on adjacent lands, visible seepage faces on canal or reservoir embankments, or return flow problems. While the district water budget may be used to develop a quantitative estimate of seepage losses, the latter indicators will provide a general idea of specific locations where seepage may be occurring.

Methods and materials used for canal lining include exposed linings (concrete, asphalt), buried membranes (plastic), earth linings (clay, soil sealants), and miscellaneous materials such as cast-in-place pipe. Methods and materials used for reservoir lining include earth compaction, earth blankets, bentonite, cement, chemical additives and flexible membranes.

Piping may be accomplished using a variety of materials including reinforced concrete, cast in place concrete, corrugated metal, PVC and other synthetics. Selection of materials for both lining and piping requires site-specific consideration of material availability, hydraulic requirements and costs.

There are many factors that influence the type of lining or pipeline chosen, and no single lining type can be recommended to satisfy all situations. Numerous publications by Reclamation and others provide detailed information concerning material selection and design. These publications are listed in the Appendix.

Questions to consider to evaluate relevance of this measure include:

? **Does your district water budget indicate significant (greater than 10%) losses in the conveyance system?**

? **Do lands adjacent to canals have excess vegetation or are they heavily vegetated with water loving plants?**

? **Do lands adjacent to canals exhibit problems with water logging as evidenced by water ponding, phreatophyte growth, and salt leaching in soils?**

Water Reuse Systems

Water reuse systems may be an effective technique for improving irrigation system efficiencies and water management within a district. In addition to reducing the required diversion amount and increasing delivery flexibility, reuse systems may provide benefits in the areas of flood protection, erosion control and water quality of receiving waters. It may also be possible to locate and schedule crop irrigation to effectively take advantage of water reuse opportunities.

The purpose of reuse systems is to capture system spills, seepage, and drainage waters for immediate or later use. In the case of operational spills, a storage facility is usually required to hold water until demand increases once again. In contrast, it may be possible to use captured drainage water on a more immediate basis, and a storage reservoir may not be required. Reuse of water potentially reduces the required amount of diversion into the overall system.

As shown in Figure 10, a reuse system will include a capture mechanism (a drainage canal or a diversion facility and reservoir) and the necessary pumping equipment and pipeline to deliver water from the capture location back into the application system. In some instances, it may be possible to use gravity for the delivery of the collected spills or drainage water.

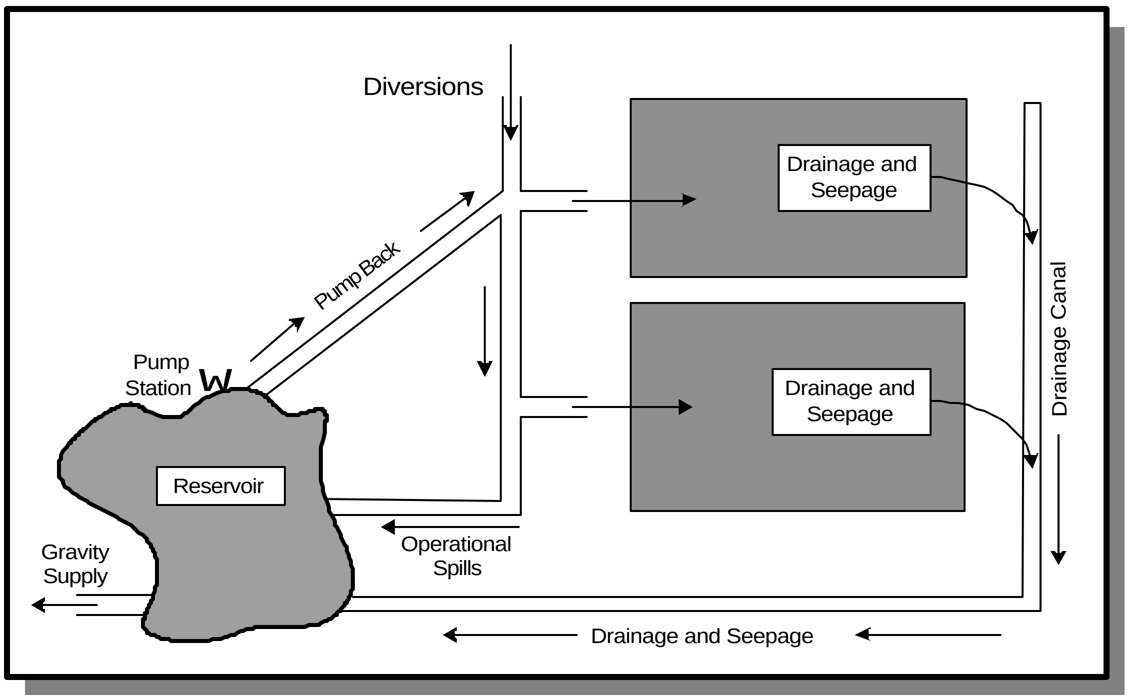


Figure 10: Irrigation Water Reuse System to Capture Spills and Drainage

In a system aimed at reuse of operational spills, it may be most efficient to capture spills at several locations in the conveyance system. Alternatively, the captured spills could be conveyed to a central storage location. The storage capacity required would typically depend on the flow rate in the service canal and the response time to changes in water demand.

Capture and reuse of operational spills as a conservation measure may be closely related to use of regulatory storage in the conveyance system. The use of regulatory reservoirs at higher points in the system may greatly improve the district's ability to respond to changing water demands and thus substantially reduce operational spills. It may also be more efficient to implement both measures and use the regulatory reservoirs for storage of pumped spill water.

In addition to capturing spilled water, capture and reuse of drainage water may be advantageous at more than one location in the system. Several drainage canals can be constructed at key locations in the service area to capture seepage from specific areas that exhibit the most significant drainage problems. This collected water is then conveyed to a central location. It may be possible to use common storage reservoirs for both captured spills and drainage waters.

To evaluate the relevance of these management measures, you should consider the following questions for your district:

? **Does your district regularly experience operational spills?**

? **Are spills frequent and do they involve significant amounts of water?**

? **Do system spills or irrigation drainage cause problems downstream from erosion, flooding, water logging, or water quality?**

? **Would a reuse system provide additional flexibility to your district in the amounts and timing of water deliveries?**

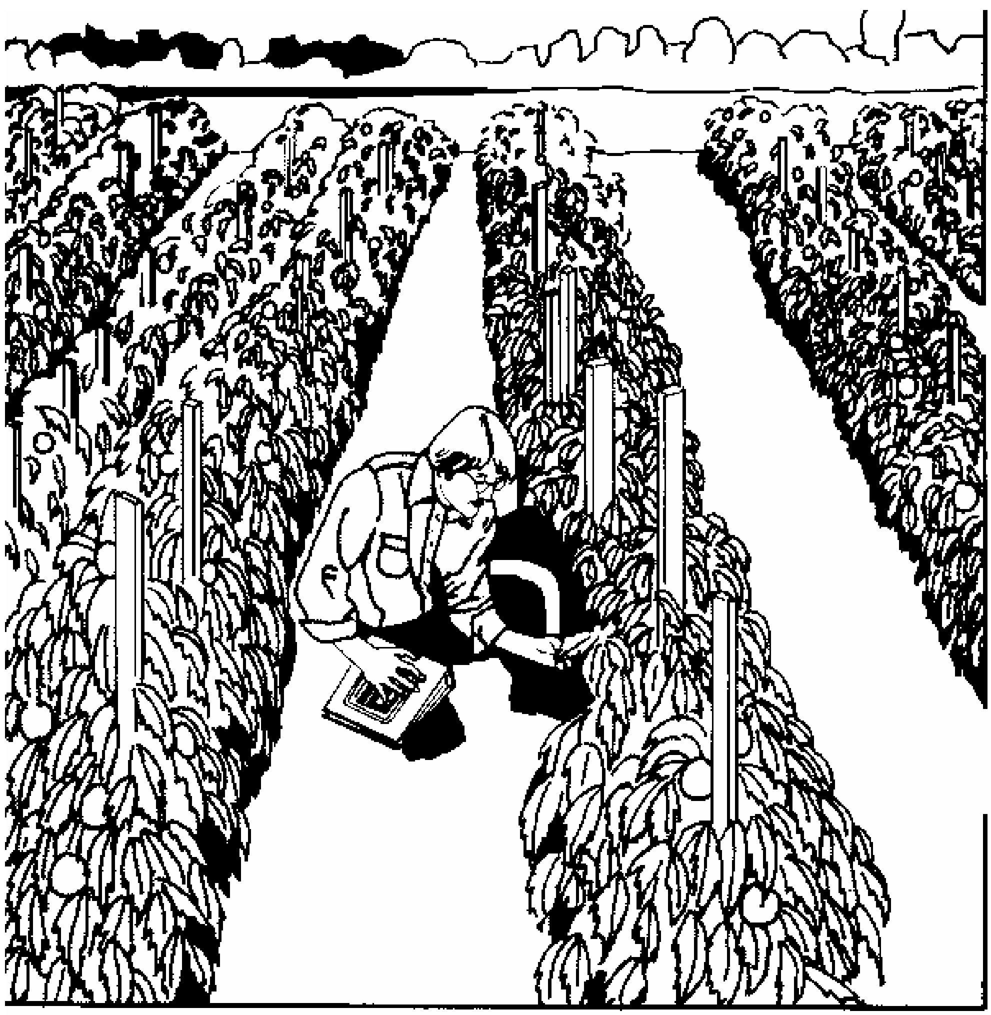
? **Could the district reduce its overall diversion through implementation of a reuse program?**

Section Four -- Assembling a Water Management Plan

This section of the Guidebook will help you prepare a document describing your water management action plan. It will:

☞ Describe the reasons for preparing a plan document

☞ Suggest how the document should be organized



WHY DO YOU NEED A WATER MANAGEMENT PLAN DOCUMENT?

There are many good reasons to prepare a document or report describing your water management plan, but the basic one is so that you can explain your plan to other people. Some of the other people who will need to understand your water management plan include:

- Members of the district Board of Directors who will need to approve the plan
- Members of the district staff who will need to implement the plan
- District water users who will want to know how the plan might affect them
- Agencies and lenders from whom the district might be seeking financing assistance
- Other local and regional water organizations with whom the district wishes to establish more cooperation
- Agencies from whom the district seeks permits or approvals
- Agencies and groups who may be unaware of the district's efforts to improve water management

For some of these people the plan will be mainly an information document. But for others, the plan may be a "sales pitch" used to convince them of the wisdom of cooperating with the district, lending money to the district, etc. Especially in this latter case, the plan document will need to be prepared in a professional way, well-organized and complete, with easy to read text, tables, and figures.

Beyond being a description of what you want to do, putting your plan in writing means that you are making a commitment to do something. It puts the district on record as moving ahead to solve problems in a progressive way. This can be very important in dealing with potential future threats to district water rights and supplies from competing uses.

You will probably also find that the process of writing your plan down will help you see where it is deficient and could be improved.

SUGGESTED OUTLINE FOR THE PLAN DOCUMENT

Your water management plan document can be thought of as a compilation and synthesis of the information developed in Phases 1 through 5 of the planning process. A suggested outline for the plan document is provided below. Each outline item might be constructed as a separate chapter or section in your management plan.

Management Plan Document--Suggested Outline

I. Description of District

II. Inventory of Water Resources

III. District Water Budget

IV. Existing Water Management Measures and Programs

V. Problems, Opportunities and Goals

VI. Evaluation of Potential Water Management Measures
   - A. Fundamental Measures
   - B. Other Measures
     - (1) Institutional Measures
     - (2) Operational Measures
     - (3) Facility Improvements

VII. Legal/Institutional/Environmental Considerations

VIII. Adopted Plan Elements
   - A. Selected Measures
   - B. Projected Results
   - C. Implementation Schedule and Budget
   - D. Monitoring

The objective of **Item I** of the plan document is to provide sufficient background information on district organization, facilities, and operations so that your reader can understand the opportunities and constraints that exist for water management improvements in the district. This is especially important if your plan document is going to be read by people who are not familiar with the district, such as bankers or lending agencies.

It may not be necessary to write a lot of prose for this part of the document. Some of the information can be conveniently displayed in tabular form. You may also be able to incorporate existing materials, such as policies and organizational charts. Often, a simple paragraph will suffice.

A district map is also a good idea for an easy-to-read management plan document. The map should show facilities, canals, laterals, diversion points, measurement locations, pumping locations, seepage, drains and spill locations and any identified problem areas.

In addition to those items, a comprehensive district description would include the following:

- District Enabling Legislation (formation authority) and Governance
- Voting and taxing authorities
- Organizational structure and personnel
- Historical irrigated acreage and trends
- Historical population and trends

Item II is documentation of the water resources inventory that you assembled in Phase 1 of the planning process. Much of this information can be displayed in tables or graphs. On the district map, you should also indicate which portions of the delivery systems are unlined, which are lined and which are piped.

Item III is your district water budget. A suggested water budget format was provided in Section Two of this Guidebook. You may find that pie charts or other graphical display methods help you visualize the various components of district inflows and outflows.

Item IV is a description of current water management practices and discussion of past management efforts.

Item V should be a brief but complete description of the water management problems you want to solve. It should also include your water management goal statements.

Item VI should be a discussion of the evaluation you have made of potential water management measures. No doubt you will have determined that some of the measures described in this Guidebook (plus others not listed) are not relevant to your situation. For these measures you may only want to provide a brief explanation of how you came to this conclusion. For those measures that you did evaluate in more detail, it would be appropriate to include a summary of the evaluation process and tabulations of any quantitative data analyses you conducted.

Item VII is a discussion of the legal, environmental and institutional issues that may arise from the water management measures under consideration. This section of your document should contribute to and supplement the technical and financial evaluations described in Item VI.

Item VIII should be a description of the elements that finally make up the water management plan you have adopted. The programs and measures that make up the plan should be described in detail, as should the expected effects and implications of those programs and measures. You should describe as clearly as possible how those measures will help you achieve your goals.

Last but not least, you should present a detailed schedule for implementing the plan and a description of the budget and financing that will be required. The schedule and budget should address both money and labor required to implement the plan.

In most cases, it should be possible to incorporate into the plan document the tables and descriptions developed earlier in the planning process. It is also possible that some parts of the plan document can be created from available district documents and data summaries. We encourage you to use such resources in order to reduce the amount of effort required to complete your plan document.

An Example Water Management Plan for the hypothetical Springfield Irrigation District follows. This example is somewhat abbreviated for space reasons, but it should provide a useful example for you to follow in creating your own planning document.

SPRINGFIELD IRRIGATION DISTRICT
WATER MANAGEMENT PLAN

DISTRICT DESCRIPTION

Springfield Irrigation District is a 10,000-acre irrigation district established in 1902. It diverts via the Springfield Canal below Spring Mountain Reservoir on the South Fork (Figure 1).

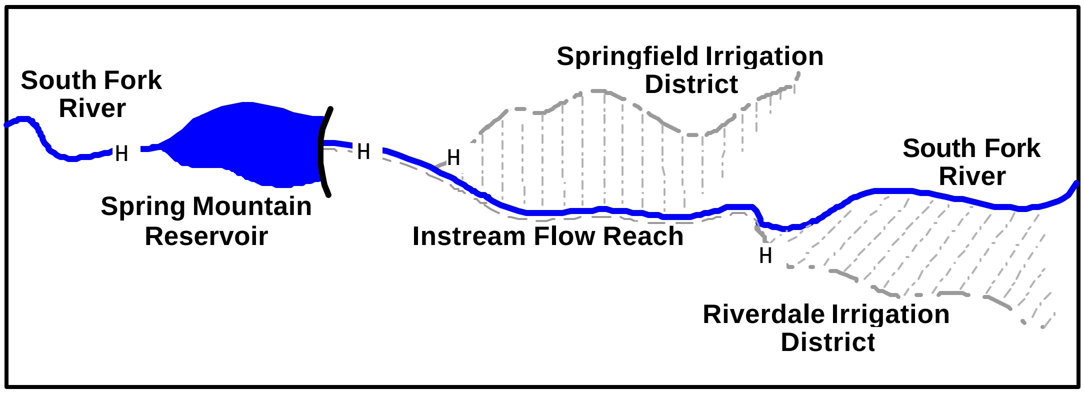


Figure 1 Springfield Irrigation District Location Map

The district is located in a semi-arid western climate, with a growing season adequate for forage, cereals and some fruits and vegetables. The terrain is gently sloping and the soils in the district are loamy with some stony, shallow sections.

Springfield currently has 55 farms. Crops grown in the district are primarily alfalfa (4,000 acres), grass hay (5,000 acres) and corn (1,000 acres). Irrigation methods are mostly flood and contour ditch with some siphon tubes for row crops.

The Springfield Canal and its laterals are unlined. There are 11 miles of laterals, 9 miles of main canal and 16 miles of open drains. The canal was originally constructed in 1902, but there have been several improvements and some realignment since then. The canal headworks consist of a concrete wall with two radial gates, installed in 1957. Most of the district's headgates, valves, checks and drop structures are at least 30 years old.

The Springfield Canal is usually run full to ensure deliveries to farmers at the lower end of the district. There are a few tailwater ponds and drainage ditches to facilitate reuse. Seepage from the canal has resulted in establishment of wetlands along the canal.

The district has a Board of Directors elected by the shareholders. The three-member board is made up of district farmers, each serving three-year terms. The district staff includes a District Manager, a secretary and two ditch riders.

District revenues are based on per-acre assessments. Every farmer in the district pays assessments based on the number of acres he or she owns. The district uses these assessments to fund operations and capital improvements.

Springfield has both a natural flow water right and a supplemental supply contract with Reclamation for storage water in Spring Mountain Reservoir. Storage water releases are requested by Springfield through an ordering process established between the district and Reclamation.

INVENTORY OF WATER RESOURCES

Springfield has a 1902 natural flow water right on the South Fork for 180 cfs. Streamflows in the South Fork are highly dependent on the previous winter's snowpack and Springfield's water right rarely yields sufficient water for irrigation in late-season months. In 1956 Springfield contracted with Reclamation for 16,000 acre-feet of supplemental supply from Spring Mountain Reservoir. Average monthly diversions of natural flow and storage water by the district are shown in Table 1. The district does not have any groundwater supplies.

Table 1
Springfield Irrigation District
Average Monthly Storage and Natural Flow Diversions

	Natural Flow, af	Storage Flow, af	Total, af
April	6,427	0	6,427
May	11,068	0	11,068
June	10,711	0	10,711
July	6,149	4,919	11,068
August	664	5,977	6,641
September	166	3,154	3,320
October	43	1,242	1,285
Total	35,227	15,293	50,520

The water quality of Springfield's sources is high but its return flows and drainage have excessive sediment and nutrients, especially in the early season.

WATER BUDGET

A district water budget was developed to help identify water supply and timing problems and opportunities. Diversion, loss and delivery data are regularly submitted to Reclamation, though only diversion data are actually measured (Table 2). Without actual measurements, the loss data submitted have been based on a combination of estimates of farm deliveries and a report of transportation losses done by Reclamation and the district about 25 years ago. Delivery data have traditionally been estimated by ditch riders and farmers, based on numbers of applications and judgment. Though operational spills are known to occur, there have been no measurements or estimates made.

Table 2
Springfield Irrigation District
Water Data Submitted to Reclamation
1965-1995 Average

	Net Supply, af*	Operational Spills, af	Transportation Losses, af	Delivered to Farms, af	Acre-feet per Acre
April	6,427	0	1,607	4,820	0.48
May	11,068	0	2,214	8,854	0.89
June	10,711	0	1,607	9,104	0.91
July	11,068	0	1,328	9,740	0.97
August	6,641	0	797	5,844	0.58
September	3,320	0	398	2,922	0.29
October	1,285	0	154	1,131	0.11
Total	50,520	0	8,105	42,415	4.00

* Combines project water and non-project water

Since the district's loss and delivery data are not verifiable, for this water budget an approach was taken to rely more heavily on the measured data: the main canal diversions. These diversions were compared to crop water requirements obtained from the county extension agent. Calculations of crop requirements for Springfield Irrigation District are shown in Table 3. Overall, the average annual crop water requirement for the district is approximately 18,500 acre-feet. The monthly distribution of crop requirements is illustrated in Figure 2.

Table 3
Springfield Irrigation District
Average Monthly Crop Water Requirements

	Corn	**Alfalfa**	**Grass**	
Acres	1,000	4,000	5,000	
	Crop Rqmt, in	Crop Rqmt, in	Crop Rqmt, in	**Total Crop Rqmt, af**
April	0.0	0.0	1.3	542
May	0.6	3.1	2.6	2,144
June	2.2	4.7	3.7	3,309
July	6.1	7.1	5.9	5,318
August	5.9	5.9	5.0	4,518
September	1.5	3.0	2.7	2,249
October	0.0	0.2	0.7	377
Total	16.3	24.0	21.8	18,458

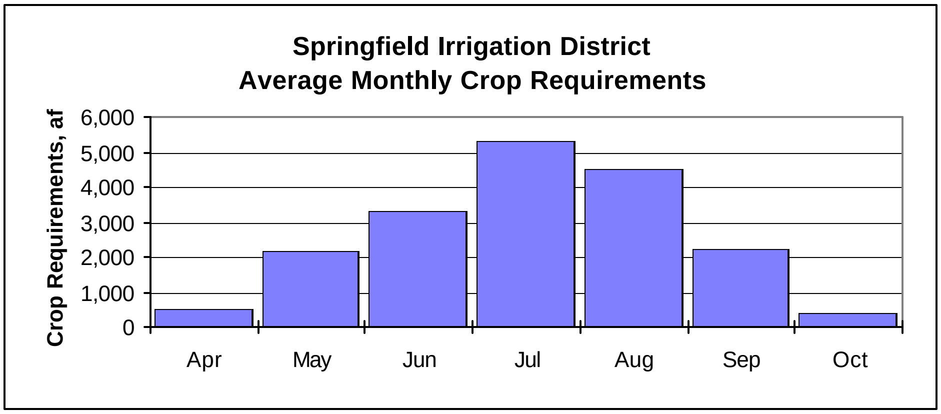


Figure 2 District-wide Average Monthly Crop Requirements

Using the crop requirements, the canal diversion data and the estimated transportation losses, overall farm efficiency was calculated (*farm efficiency = crop requirement ¸ delivery*). These calculations gave an overall, annual farm efficiency of 44% (Table 4). If the transportation loss values are accurate, then the overall farm efficiency fluctuates from 11% to 77% during the irrigation season (Figure 3). This enormous range in farm efficiency suggests an unlikely situation, where farms are literally flooded in spring. It is more likely that the transportation loss value is incorrect and that there are other types of losses, like operational spills, taking place, especially early in the season.

Table 4
Springfield Irrigation District
Average Monthly Farm Efficiency Calculation

	Average Canal Diversion, af	Delivered to Farms, af	Total Crop Requirement, af	Farm Efficiency
April	6,427	4,820	542	0.11
May	11,068	8,854	2,144	0.24
June	10,711	9,104	3,309	0.36
July	11,068	9,740	5,318	0.55
August	6,641	5,844	4,518	0.77
September	3,320	2,922	2,249	0.77
October	1,285	1,131	377	0.33
Total	50,520	42,415	18,458	0.44

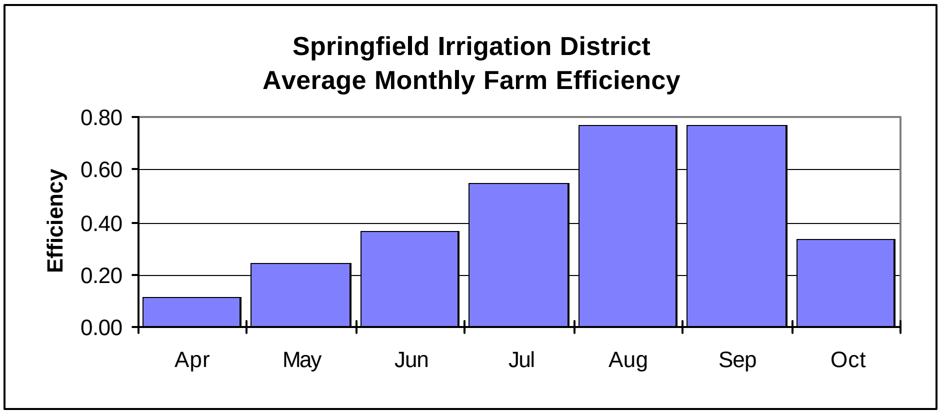


Figure 3 Overall District-wide Farm Efficiency

To better understand the system losses, an overall district-wide efficiency, which reflects all losses to seepage, spills and other kinds of waste, was calculated (*overall efficiency = crop requirement ¸ canal diversion*). Annually, for Springfield, the average overall efficiency value is 37% (Table 5). Spring efficiencies are as low as 8%, suggesting that there are substantial early season losses or waste.

Table 5
Springfield Irrigation District
Overall Efficiency Calculation

	Canal Diversion, af	Total Crop Rqmt, af	Overall Efficiency
April	6,427	542	0.08
May	11,068	2,144	0.19
June	10,711	3,309	0.31
July	11,068	5,318	0.48
August	6,641	4,518	0.68
September	3,320	2,249	0.68
October	1,285	377	0.29
Total	50,520	18,458	0.37

Finally, district-wide diversion requirements were calculated to get a picture of the match between diversion requirements and actual diversions (Table 6 and Figure 4). These estimates are based on an assumption that 200% of the crop water requirement must be diverted to fulfill the entire district's water requirement. This assumption was based on efficiency tables in the state's irrigation guide. For soils, slopes and irrigation methods common to Springfield, an overall irrigation efficiency of 50% is reasonable.

Table 6 Springfield Irrigation District Average Monthly Diversion Requirement		
	Total Crop Rqmt, af	Diversion Requirement, af*
April	542	1,083
May	2,144	4,288
June	3,309	6,618
July	5,318	10,637
August	4,518	9,037
September	2,249	4,498
October	377	753
Total	18,458	36,915

*Assumes 50% overall efficiency

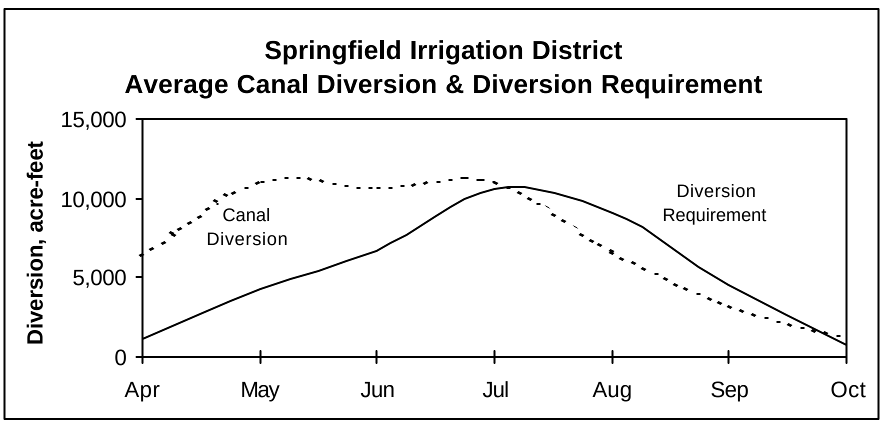


Figure 4 District-wide Diversions and Diversion Requirements

The following conclusions were made from the water budget analysis:

- Overall, average district-wide efficiency is 0.37
- Approximately 32,000 acre-feet of diversion goes unused by crops in an average year
- Historical farm delivery estimates are probably incorrect
- The district is diverting too much water in the early season. This is likely the result of habit and conservatism on the part of both the district and its irrigators
- Early-season excess natural flow diversions may be competing with junior storage rights at Spring Mountain Reservoir, possibly jeopardizing late-season storage supplies

- Wetlands and drainage problems are likely evidence of excessive losses and spills in the early season
- The water budget needs to be revisited and revised as better data becomes available

EXISTING WATER MANAGEMENT MEASURES AND PROGRAMS

Springfield does not have formal water management measures and programs. The district has historically operated by diverting to its capacity when natural flow water was available under its water right. Each season, as Springfield runs out of natural flow water it begins ordering storage water from Reclamation. The district has made water conservation materials available to its farmers whenever they are supplied by the county, state, Reclamation or NRCS. Some of the district farmers have been able to convert to using gated pipe.

PROBLEMS, OPPORTUNITIES AND GOALS

The water budget analysis helped to identify several key problems. First, there is a significant mismatch between the timing of crop irrigation requirements and diversions by the Springfield Canal. Second, there are substantial, unexplained losses in the early season, and third, there is insufficient data to clearly determine where and how losses are occurring.

The water budget analysis did reveal, however, that on an annual basis there is probably enough water to meet the district's irrigation demands.

In addition to the water budget analysis, extensive discussions were held with district irrigators and community representatives to determine the key problems the district, its farmers and its neighbors were facing. These discussions identified many issues. Through an iterative process of examination and re-examination, it became apparent that some of the issues were really symptoms of more basic underlying problems. Ultimately, most of the symptoms could be ascribed to two basic problems: scheduling and efficiency.

¨ **Basic problem: Scheduling**

- Symptom: there isn't enough late season water
- Symptom: imprecise timing of the supply prevents growing certain crops
- Symptom: boaters and fishermen at Spring Mountain Reservoir are pressing for higher, late-season lake levels

- Symptom: the state wants to improve the spring-time streamflows in the reach of the South Fork just below Springfield's headgate

¨ **Basic problem: Efficiency**

- Symptom: there are frequently insufficient deliveries to the lower end of the district compared to the upper end of the district
- Symptom: efficient irrigators are, in effect, paying more per acre-foot than inefficient irrigators
- Symptom: there are large seepage losses in portions of the Springfield Canal
- Symptom: substantial water is lost when farmers shut off their laterals and the canal spills
- Symptom: downstream municipal users are concerned about the quality of Springfield's drainage and return flow waters
- Symptom: Springfield Canal seepage supports wetlands that have become important migratory-bird habitats

Once the basic problems and their symptoms were understood, the district defined its goals for the water management plan. Again, development of the district's goals was an iterative process, requiring discussions with irrigators and the community. Through this iterative process, it became apparent that these problems and symptoms were related to how the district managed water deliveries and how the district worked with other South Fork basin water users. Springfield's board of directors ultimately identified two broad goals:

GOAL 1: IMPROVE SPRINGFIELD'S WATER DELIVERY SERVICE

GOAL 2: TAKE A LEADERSHIP ROLE IN THE SOUTH FORK BASIN IN WATER RESOURCE ISSUES

Since these goals are very broad they have been divided into sub-goals or objectives.

¨ **GOAL 1**

- Objective: Improve delivery scheduling
- Objective: Improve delivery facilities
- Objective: Improve water delivery fairness

- Objective: Improve water use efficiency
- Objective: Improve measurement capabilities

¨ **GOAL 2**

- Objective: Improve water use efficiency
- Objective: Improve reservoir recreation
- Objective: Improve downstream water quality
- Objective: Improve South Fork fisheries

EVALUATION OF POTENTIAL WATER MANAGEMENT MEASURES

Water management measures that were considered for the management plan are listed in Tables 7 and 8. Measures were evaluated from both a technical standpoint and a legal, institutional and environmental standpoint.

Technical Evaluation

The technical evaluation examined the measures from a feasibility and cost standpoint. Estimates of water supply and cost effects of eight potential water management measures were made with assistance from Reclamation, NRCS and extension service personnel. Irrigation districts that have implemented some of the measures were also contacted, to collect data on effects. Results of the investigations are summarized in Table 7. In the table, water supply "amount," "efficiency" and "equity" refer to the effects of the measure on district supplies, efficiency of water use and fairness of water service within the district, respectively. "No change" indicates that the measure is not likely to have an effect in that category. A plus sign indicates an increase, a negative sign means a decrease and a question mark indicates that the effect has not been predicted or is unclear. Annualized costs include both construction and operation and maintenance costs.

Measures that were evaluated in detail include incentive pricing, canal lining, irrigation scheduling and education. Incentive pricing had very low construction costs but relatively high operating costs. In the short-term incentive pricing was not expected to increase overall water supply but it was expected to cause a redistribution of existing supplies away from inefficient water users to more efficient water users. In the long-term, it was expected to increase overall district efficiency.

Canal lining was expected to have relatively high construction costs but negligible operating costs. The effects on water supply were expected to be immediate, with approximately 10,000 acre-feet per year saved by lining the main canal. This additional 10,000 acre-feet could be put to several different uses within or outside the district. There are a number of environmental issues associated with this measure that are discussed in the next section.

Irrigation scheduling had relatively low construction costs and relatively high operating costs. The measure was not expected to increase overall supplies for the district, nor was it expected to have as dramatic short-term effects as canal lining. Over the long-term, it was expected to increase crop quality and quantity and provide more flexibility to district farmers.

Education programs were the least expensive measures investigated. They would have little short-term effect on water supply or water use efficiency. Effects would be seen over the long-term, as district irrigators adopted the suggested practices and facilities.

Table 7
Potential Water Management Measures
Technical Evaluation

Effects / Alternatives	Water Supply			Annualized Costs
	Amount	Efficiency	Equity	$/yr
Incentive pricing	no change	+	+	10,000
Canal lining	+10,000 af	+	?	6,500
Irrigation scheduling	no change	+	+	20,000
Canal enlargement	no change	no change	+	18,000
Regulatory storage	no change	?	?	77,500
Sprinklers	no change	+	?	194,000
Education	no change	+	+	1,200
Groundwater	+10,000 af	?	?	238,000

Legal, Institutional and Environmental Evaluation

Discussions were also held with Springfield's attorneys, Reclamation personnel, the state engineer's office and the state environmental office to assess potential legal, institutional and environmental issues that might be associated with the water management measures.

Results of those investigations are summarized in Table 8. Again, the measures investigated in detail include incentive pricing, canal lining, irrigation scheduling and education programs.

Incentive pricing was considered unlikely to have federal or local issues associated with it, but there may be some restrictions under state law that limit Springfield's flexibility to implement the measure. Incentive pricing, if it encourages water use efficiency, was expected to reduce drainage. Impacts to wetlands supported by the main canal are unknown.

Canal lining was expected to have implications at federal and state levels because it would likely eliminate the seepage which supports wetlands. National Environmental Policy Act (NEPA) compliance might be required. Drainage from the district was expected to decrease with this measure, potentially improving water quality downstream of the district.

Irrigation scheduling was not expected to have federal, state or local implications, though there may be effects to the wetlands supported by the main canal. Again, drainage from the district was expected to decrease with irrigation scheduling.

Education programs were not expected to have legal or institutional issues associated with them.

Though it wasn't investigated in detail, canal enlargement was expected to have water rights implications because enlargement would exceed the permit amount of Springfield's natural flow water right.

Regulatory storage was also expected to have legal and environmental implications, depending on the site selected. Because it would reduce operational spills, regulatory storage would reduce drainage from the district. Its effects on wetlands is unknown.

Drilling groundwater wells as supplemental supply was expected to have state and water right implications. Drilling and pumping permits would have to be obtained and it would have to be demonstrated that there would be no injury to surface water users from groundwater withdrawals. The impacts on drainage and wetlands are unknown.

Table 8 Potential Water Management Measures Legal, Institutional and Environmental Evaluation						
Issues / Alternatives	Institutional			Legal	Environmental	
	Federal	State	Local	Water Rights	Drainage	Wetlands
Incentive pricing	none	possible	none	none	-	?
Canal lining	possible	possible	possible	none	?	-
Irrigation scheduling	none	none	none	none	-	?
Canal enlargement	possible	possible	possible	possible	+	+
Regulatory storage	possible	possible	possible	possible	-	?
Sprinklers	none	none	none	none	-	?
Education	none	none	none	none	?	?
Groundwater	possible	possible	none	possible	?	?

ADOPTED PLAN ELEMENTS

Selected Measures

Measures that were eliminated without detailed investigation were those that involved expensive construction projects. Measures that were selected to be examined in detail were those that helped to achieve the service and leadership goals of the district, without being too costly.

Of the four measures investigated in detail, canal lining and incentive pricing were eliminated for the near future. Per mile costs of canal lining were high enough that it was dismissed as a possible measure for implementation. Incentive pricing has a lot of promise for achieving the district's fairness objective, though it was felt that acceptance and confidence in the system would depend on having more adequate measuring devices.

The final water management plan has three programs: an irrigation scheduling program, an education program and a measuring device installation program. After evaluation, these three programs were considered as having the most potential, within reasonable costs, to achieving Springfield's goals of improving the district's water delivery service and of providing leadership in the South Fork basin.

Irrigation Scheduling Program

The irrigation scheduling program can be implemented with technical assistance from the county extension agent. She has agreed to calculate and transmit daily evapotranspiration and effective precipitation data to the local newspaper each day. The district will use this information with crop acreage numbers to estimate and schedule diversions from the South Fork. Reclamation has committed to working with Springfield to better conserve springtime flows for recreation and late season irrigation use.

Education Program

The education program will include mobile demonstration projects and workshops on irrigation scheduling. The demonstration projects will include movable surge valves and gated pipes.

Measuring Device Installation Program

The measuring-device installation program will add ten flumes and weirs per year to measure flows at turnouts. The program also includes adding eight staff gages at drains and wasteways to help identify locations and amounts of losses, spills and other waste.

Projected Results

Irrigation scheduling is expected to ultimately reduce early season diversions by approximately 16,000 acre-feet and to increase late season diversions by about 4,000 acre-feet. Early season drainage problems are projected to be reduced at a level of magnitude similar to the reduction in early season diversion.

Canal maintenance requirements are expected to be lower because of lower flows in the early season. Service to district irrigators will improve with better timing of deliveries and more late-season water. Other South Fork basin water users will benefit by higher water levels in Spring Mountain Reservoir and improved quality of drainage and return flows.

Irrigation scheduling, education programs and measuring devices do not directly address the problems of inadequate deliveries to the lower end of the district. Possible impacts to those irrigators may be positive or negative. The situation for irrigators at the lower end of the system may improve if irrigators at the upper end actively participate in irrigation scheduling and reduce their demands. The situation may deteriorate if irrigation scheduling results in higher demands during peak periods, further stressing the canal. Because so little is understood about the locations and amounts of losses in the system, the district is hesitant to engage in a major construction effort to increase the canal capacity or arbitrarily line sections of the canal. However, after measuring devices have been installed, the causes of the delivery problems will be more clear. It may be that the next management plan recommends construction projects as the most cost-effective solutions.

Implementation Schedule and Budget

An implementation schedule and budget for the water management plan are summarized in Table 9.

Table 9
Springfield Irrigation District
Implementation Schedule and Budget

Activity	Scheduled Start	Budget
Publish ET and effective precip. information	Beginning of this irrigation season	$2,000
Coordinate new ordering system with Reclamation	Immediately	$1,000
Demonstration programs	Next season	$5,000
Install measuring devices at turnouts, 10 per year.	Begin now, finish in five years	$10,000/yr
Install staff gages at drains and wasteways	This season	$1,200

Monitoring

A monitoring program is essential to determine the effectiveness of the new program. It will also be key to identifying opportunities for further management improvements. Monitoring efforts will include:

- Data collection from gages installed at turnouts
- Data collection from new staff gages on wasteways and drains
- Periodic collection of feedback from district irrigators
- Periodic comparison of crop requirement estimates with diversions
- Periodic inspection of canal conditions
- Periodic evaluation of selected programs toward achieving Springfield's goals

Glossary

Acre-foot: A volume of water that would cover one acre to a depth of one foot, or 325,850 gallons of water.

Application efficiency: The ratio of the average depth of irrigation water infiltrated and stored in the root zone to the average depth of irrigation water applied, expressed as a percent.

Applied water: Water delivered to a user. Also called delivered water. Applied water may be used for either inside uses or outside watering. It does not include precipitation or distribution losses. It may apply to metered or unmetered deliveries.

Aquifer: Underground water-bearing geologic formation or structure.

Arable: Having soil or topographic features suitable for cultivation.

Artificial drains: Man-made or constructed drains.

Available capacity: The amount of water held in the soil that is available to the plants.

Check dam: Small barrier constructed in a gully or other small watercourse to decrease flow velocity, minimize channel scour, and promote deposition of sediment.

Conduit: Any open or closed channel intended for the conveyance of water.

Conjunctive use: The coordinated use of surface water and groundwater resources.

Conservation: Increasing the efficiency of energy use, water use, production, or distribution.

Consumptive use (evapotranspiration): Combined amounts of water needed for transpiration by vegetation and for evaporation from adjacent soil, snow, or intercepted precipitation. Also called: Crop requirement, crop irrigation requirement, consumptive use requirement.

Continuous-flow irrigation: System of irrigation water delivery where each irrigator receives his allotted quantity of water at a continuous rate.

Contour ditch: Irrigation ditch laid out approximately on the contour.

Contour farming: System of farming used for erosion control and moisture conservation whereby field operations are performed approximately on the contour.

Contour flooding: Method of irrigation by flooding from contour ditches.

Contour furrows: Furrows plowed approximately on the contour on pasture or rangeland to prevent soil loss and increase infiltration. Also furrows laid out on the contour for irrigation purposes.

Control structure: Water regulating structure, usually for open conduits.

Conveyance loss: Loss of water from a channel or pipe during conveyance, including losses due to seepage, leakage, evaporation and transpiration by plants growing in or near the channel.

Conveyance system efficiency: The ratio of the volume of water delivered to users in proportion to the volume of water introduced into the conveyance system.

Critical habitat: Areas that contain essential habitat features important for the conservation of a species. Designated critical habitat may require special management or protection under Section 7 of the Endangered Species Act.

Crop irrigation requirement: Quantity of water, exclusive of effective precipitation, that is needed for crop production.

Crop root zone: The soil depth from which a mature crop extracts most of the water needed for evapotranspiration. The crop root zone is equal to effective rooting depth and is expressed as a depth in inches or feet. This soil depth may be considered as the rooting depth of a subsequent crop, when accounting for soil moisture storage in efficiency calculations.

Cropping pattern: The acreage distribution of different crops in any one year in a given farm area such as a county, water agency, or farm. Thus, a change in a cropping pattern from one year to the next can occur by changing the relative acreage of existing crops, and/or by introducing new crops, and/or by cropping existing crops.

Crop water requirement: Crop consumptive use plus the water required to provide the leaching requirements.

Cubic feet per second (ft^3/s): A rate of streamflow; the volume, in cubic feet, of water passing a reference point in 1 second.

Deep percolation: The movement of water by gravity downward through the soil profile beyond the root zone; this water is not used by plants.

Demand scheduling: Method of irrigation scheduling whereby water is delivered to users as needed and which may vary in flow rate, frequency and duration. Considered a flexible form of scheduling.

Distribution efficiency: Measure of the uniformity of irrigation water distribution over a field.

Distribution loss: See conveyance loss.

Distribution system: System of ditches, or conduits and their appurtenances, which conveys irrigation water from the main canal to the farm units.

District: An entity that has a contract with the Reclamation for the delivery of irrigation water. Such entities include, but are not limited to: canal companies; conservancy districts, ditch companies, irrigation and drainage districts, irrigation companies, irrigation districts, reclamation districts, service districts, storage districts, water districts, and water users associations.

Ditch: Constructed open channel for conducting water. See canal, drain.

Diversion (water): Removal of water from its natural channels for human use.

Diversion (structure): Channel constructed across the slope for the purpose of intercepting surface runoff; changing the accustomed course of all or part of a stream.

Drainage: Process of removing surface or subsurface water from a soil or area.

Drainage system: Collection of surface and/or subsurface drains, together with structures and pumps, used to remove surface or groundwater.

Drip (trickle) irrigation: An irrigation method in which water is delivered to or near each plant in small-diameter plastic tubing. The water is then discharged at a rate less than the soil infiltration capacity through pores, perforations, or small emitters on the tubing. The tubing may be laid on the soil surface, be shallowly buried, or be supported above the surface (as on grape trellises).

Drought: Climatic condition in which there is insufficient soil moisture available for normal vegetative growth.

Erosion: A gradual wearing away of soil or rock by running water, waves, or wind.

Evaporation: Water vapor losses from water surfaces, sprinkler irrigation, and other related factors.

Evapotranspiration: The quantity of water transpired by plants or evaporated from adjacent soil surfaces in a specific time period. Usually expressed in depth of water per unit area.

Fallow: Land plowed and tilled and left unplanted.

Farm consumptive use: Water consumptively used by an entire farm, excluding domestic use. See irrigation requirement, consumptive use, evapotranspiration.

Farm distribution system: Ditches, pipelines and appurtenant structures which constitute the means of conveying irrigation water from a farm turnout to the fields to be irrigated.

Farm loss (water): Water delivered to a farm which is not made available to the crop to be irrigated.

Field capacity: Depth of water retained in the soil after ample irrigation or heavy rain when the rate of downward movement has substantially decreased, usually one to three days after irrigation or rain, expressed as a depth of water in inches or feet. Also called field moisture capacity.

Fixed amount-frequency scheduling: Method of irrigation scheduling that involves water delivery at a fixed rate or a fixed volume and at constant intervals. Examples include rotation and continuous flow methods. Considered a rigid form of scheduling.

Flood control pool: Reservoir volume reserved for flood runoff and then evacuated as soon as possible to keep that volume in readiness for the next flood.

Flood irrigation: Method of irrigating where water is applied from field ditches onto land which has no guide preparation such as furrows, borders or corrugations.

Frequency demand scheduling: Method of irrigation scheduling similar to demand scheduling, but typically involves a fixed duration of the delivery, such as 24 hours. This method is considered flexible, although somewhat less so than demand scheduling from the water users perspective.

Gate (irrigation): Structure or device for controlling the rate of flow into or from a canal or ditch.

Gated pipe: Portable pipe with small gates installed along one side for distributing irrigation water to corrugations or furrows.

Gauge: Device for registering water level, discharge, velocity, pressure, etc.

Gauge height: Elevation of water surface measured by a gauge.

Gauging station: Specific location on a stream where systematic observations of hydrologic data are obtained through mechanical or electrical means.

Gravity irrigation: Irrigation method that applies irrigation water to fields by letting it flow from a higher level supply canal through ditches or furrows to fields at a lower level.

Groundwater: (1) Water that flows or seeps downward and saturates soil or rock, supplying springs and wells. The upper level of the saturated zone is called the water table. (2) Water stored underground in rock crevices and in the pores of geologic materials that make up the earth's crust. That part of the subsurface water which is in the zone of saturation; phreatic water.

Groundwater mining (overdraft): Pumping of groundwater for irrigation or other uses, at rates faster than the rate at which the groundwater is being recharged.

Groundwater recharge: The flow to groundwater storage from precipitation, infiltration from streams, and other sources of water.

Groundwater table: The upper boundary of groundwater where water pressure is equal to atmospheric pressure, i.e., water level in a bore hole after equilibrium when groundwater can freely enter the hole from the sides and bottom.

Growing season: The period, often the frost-free period, during which the climate is such that crops can be produced.

Hydraulic efficiency: Efficiency of a pump or turbine to impart energy to or extract energy from water. The ability of hydraulic structure or element to conduct water with minimum energy loss.

Hydrology: Science dealing with the properties, distribution and flow of water on or in the earth.

Infiltration rate: The rate of water entry into the soil expressed as a depth of water per unit of time in inches per hour or feet per day. The infiltration rate changes with time during irrigation.

Instream flows: Water flows for uses within a defined stream channel e.g., flows intended for fish and wildlife.

Irrigated acreage: Irrigable acreage actually irrigated in any one year. It includes irrigated cropland harvested, irrigated pasture, cropland planted but not harvested, and the acreage in irrigation rotation used for soil building crops.

Irrigation: Application of water to lands for agricultural purposes.

Irrigation check: Small dike or dam used in the furrow alongside an irrigation border to make the water spread evenly across the border.

Irrigation efficiency: The ratio of the average depth of irrigation water that is beneficially used to the average depth of irrigation water applied, expressed as a percent. Beneficial uses include satisfying the soil water deficit and any leaching requirement to remove salts from the root zone.

Irrigation frequency: Time interval between irrigations.

Irrigation requirement: Quantity of water, exclusive of effective precipitation, that is required for crop production.

Land classification: Reclamation's systematic placing of lands into classes based on their suitability for sustained irrigated farming. Land classes are defined by productivity, with class 1 being the most productive. For other classes, the equivalent acreage to class 1 for the same productivity is defined (class 1 equivalency).

Land leveling: Process of shaping the land surface for better movement of water and machinery over the land. Also called land forming, land shaping, or land grading.

Land retirement: Permanent removal of land from agricultural production.

Land-use planning: Development of plans for the use of land that will, over a long period, best serve the general public.

Leaching: Removal of soluble material from soil or other permeable material by the passage of water through it.

Leaching requirement: Quantity of irrigation water required for transporting salts through the soil profile to maintain a favorable salt balance in the root zone for plant development.

Lining: Protective covering over the perimeter of a conduit, reservoir, or channel to prevent seepage losses, to withstand pressure, or to resist erosion.

Lysimeter: An isolated block of soil, usually undisturbed and in situ, for measuring the quantity, quality, or rate of water movement through or from the soil.

Neutron probe: An instrument used to estimate soil moisture. Relates the rate of attenuation in pulsed neutron emissions to soil water content.

Nonconsumptive water uses: Water uses that do not substantially deplete water supplies, including swimming, boating, water-skiing, fishing, maintaining stream related fish and wildlife habitat, and generating hydropower.

On-farm: Activities (especially growing crops and applying irrigation water) that occur within the legal boundaries of private property.

On-farm irrigation efficiency: The ratio of the volume of water used for consumptive use and leaching requirements in cropped areas to the volume of water delivered to a farm (applied water).

Operational losses: Losses of water resulting from evaporation, seepage, and spills.

Operational waste: Water that is lost or otherwise discarded from an irrigation system after having been diverted into it as part of normal operations.

Pan evaporation: Evaporative water losses from a standardized pan. Pan evaporation is sometimes used to estimate crop evapotranspiration and assist in irrigation scheduling.

Parshall flume: A calibrated device, based on the principle of critical flow, used to measure the flow of water in open conduits. Formerly termed the Improved Venturi Flume.

Percolation: Downward movement of water through the soil profile or other porous media.

Percolation rate: (1) The rate at which water moves through porous media, such as soil; and (2) intake rate used for designing wastewater absorption systems.

Perforated pipe (sprinkler): Pipe designed to discharge water through small, multiple, closely spaced orifices or nozzles, placed in a segment of its circumference for irrigation purposes.

Permanent wilting point: Soil water content below which plants cannot readily obtain water and permanently wilt. Sometimes called "permanent wilting percentage."

Permeable: Having pores or openings that permit liquids or gasses to pass through.

Permeability:

1. **Qualitative**: The ease with which gases, liquids, or plant roots penetrate or pass through a layer of soil or porous media.

2. **Quantitative**: The specific soil property designating the rate at which gases and liquids can flow through the soil or porous media.

Permeameter: Device for containing the soil sample and subjecting it to fluid flow in order to measure permeability or hydraulic conductivity.

Phreatophyte: Water plant.

Potential evapotranspiration: Rate at which water, if available, would be removed from soil and plant surfaces.

Pump-back system: A return flow system in which tailwater is pumped back to the head of an irrigation ditch for reuse.

Reservoir: Body of water, such as a natural or constructed lake, in which water is collected and stored for use.

Return flow: That portion of the water diverted from a stream which finds its way back to the stream channel, either as surface or underground flow.

Return-flow system: A system of pipelines or ditches to collect and convey surface or subsurface runoff from an irrigated field for reuse. Sometimes called a “reuse system.”

Reuse system: See return-flow system.

Riparian: Of, on, or pertaining to the bank of a river, pond, or lake.

Root zone: That depth of soil which plant roots readily penetrate and in which the predominant root activity occurs.

Runoff: The portion of precipitation, snow melt, or irrigation that flows over the soil, eventually making its way to surface water supplies.

Saline: The condition of containing dissolved or soluble salts. Saline soils are those whose productivity is impaired by high soluble salt content. Saline water is that which would impair production if used to irrigate sensitive crops without adequate leaching to prevent soil salinization.

Second-foot: See cubic feet per second.

Sediment load: Amount of sediment carried by running water.

Sedimentation: Deposition of waterborne sediments due to a decrease in velocity and corresponding reduction in the size and amount of sediment which can be carried.

Seepage: The movement of water into and through the soil from unlined canals, ditches, and water storage facilities.

Seepage loss: Water loss by capillary action and slow percolation.

Siphon tube: Relatively short, light-weight, curved tube used to convey water over ditch banks to irrigate furrows or borders.

Slope: Degree of deviation of a surface from the horizontal, usually expressed in percent or degrees.

Soil classification: Systematic arrangement of soils into classes of one or more categories or levels to meet a specific objective. Broad groupings are made on the basis of general characteristics, and subdivisions are made on the basis of more detailed differences in specific properties.

Soil conservation: Protection of soil against physical loss by erosion and chemical deterioration by the application of management and land-use methods that safeguard the soil against all natural and human-induced factors.

Soil moisture: Water stored in soils.

Sprinkler irrigation: A method of irrigation in which the water is sprayed, or sprinkled, through the air to the ground surface.

Sprinkler systems:

1. **Boom type**: An elevated, cantilevered sprinkler(s) mounted on a central stand. The sprinkler boom rotates about a central pivot.

2. **Farm system**: System which will properly distribute the required amount of water to an entire farm.

3. **Field system**: That part of a farm system which covers one field or area for which it is designed.

4. **Hand move**: Method of moving the sprinkler system by uncoupling and picking up the pipes manually, requiring no special tools. This includes systems in which lateral pipes are loaded and unloaded manually from racks or trailers used to move the pipes from one lateral setting to another.

5. **Mechanized**: System which is moved either by engine power, tractor power, water power, or hand power on wheels or skids. Generally considered as any type of system that can be moved without carrying manually.

6. **Permanent**: System consisting of permanent underground piping with either permanent risers for sprinklers, or quick coupling valves, in such a manner that sprinklers may be attached.

7. **Self-propelled system**: Portable system which moves continuously when in operation. May rotate about a pivot in the center of field, or move laterally across the field in a predetermined direction.

8. **Semi-portable**: Systems designed with permanent pumping units and mains, but with portable sprinkler laterals.

9. **Side-roll system**: System, mounted on wheels, usually employing the lateral pipe line as an axle, where the lateral is moved at right angles to the mainline by rotating the pipeline either by hand or by engine power.

10. **Solid set**: System, either permanent or portable, which covers the complete field with pipes and sprinklers in such a manner that all the field can be irrigated without moving any of the system.

11. **Towed system**: System where lateral lines are mounted on wheels, casters, sleds, or skids, and are pulled or towed in the field to be irrigated in a direction approximately parallel to the lateral.

Subirrigation: Applying irrigation water below the ground surface either by raising the water table within or near the root zone, or by use of a buried perforated or porous pipe system which discharge directly into the root zone.

Surface soil: Upper part of the soil ordinarily moved in tillage, or its equivalent in uncultivated soils, about 10 to 20 cm in thickness.

Surface water: An open body of water such as a river, stream, or lake.

Surge irrigation: A surface irrigation technique wherein flow is applied to furrows (or less commonly, borders) intermittently during a single irrigation set.

Tailwater: Applied irrigation water that runs off the lower end of a field. Tailwater is measured as the average depth of runoff water, expressed in inches or feet.

Tensiometer: Instrument, consisting of a porous cup filled with water and connected to a manometer or vacuum gauge, used for measuring the soil-water matric potential.

Varied amount - fixed frequency scheduling: Method of irrigation scheduling that involves water deliveries that vary in flow rate or amount over time, but that are made at constant intervals. An example is the rotation method when a minimum flow is delivered almost continuously. Considered a rigid term of scheduling.

Water budget: An analytical tool whereby the sum of the system inflows equals the sum of the system outflows.

Water conveyance efficiency: Ratio of the volume of irrigation water delivered by a distribution system to the water introduced into the system.

Water delivery system: Reservoirs, canals, ditches, pumps, and other facilities to move water.

Water demand: Water requirements for a particular purpose, as for irrigation, power, municipal supply, plant transpiration or storage.

Water holding capacity: Amount of soil water available to plants. See available soil water.

Water transfers: Selling or exchanging water or water rights among individuals or agencies.

Westwide: The 17 Western states in which Reclamation projects are located; namely, Arizona, California, Colorado, Idaho, Kansas, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oklahoma, Oregon, South Dakota, Texas, Utah, Washington, and Wyoming.

Wetlands: Lands including swamps, marshes, bogs, and similar areas such as wet meadows, river overflows, mud flats, and natural ponds. An area characterized by periodic inundation or saturation, hydric soils, and vegetation adapted for life in saturated soil conditions.

Wetted perimeter: Length of the wetted contact between a conveyed liquid and the open channel or closed conduit conveying it, measured in a plane at right angles to the direction of flow.

Wilting point: The soil water content below which plants growing in that soil will remain wilted even when transpiration is nearly eliminated.

Appendix

Resources

Documents

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DK-411, P.O. Box 1017
Bismarck, ND 58502-1017

(701) 250-4598 (phone)

State Water Conservation Programs

Program Coordinator
South Dakota Department of Environment & Natural Resources Office
523 East Capitol Avenue
Pierre, SD 57501

(605) 773-3352 (phone)

State Office of County Cooperative Extension Programs

Cooperative Extension Services
Box 2207D
Brookings, SD 57007

(605) 688-4792 (phone)

USDA State Conservationist

State Conservationist
Natural Resources Conservation Service
Federal Building
200 Fourth Street, SW
Huron, SD 57350-2475

(605) 352-1200 (phone)

Texas

USBR Regional and Area Office Water Conservation Program Coordinators

Program Coordinator
Oklahoma-Texas Area Office
OT-240, 420 W. Main Street
Oklahoma City, OK 73102-4435

(512) 916-5641 (phone)

State Water Conservation Programs

Program Coordinator
Chief, Conservation Section
Texas Water Development Board
P. O. Box 13231
Austin, TX 78711-3231

(512) 463-7983 (phone)

State Office of County Cooperative Extension Programs

Texas A&M University
Cooperative Extension Services
College Station, TX 77843

(409) 845-7808 (phone)

USDA State Conservationist

State Conservationist
Natural Resources Conservation Service
W.R. Poage Building
101 S. Main Street
Temple, TX 76501-7682

(817) 774-1214 (phone)

Utah

USBR Regional and Area Office Water Conservation Program Coordinators

Program Coordinator
Upper Colorado Regional Office
UC-295, 125 South State Street
Room 6107
Salt Lake City, UT

(801) 524-3745 (phone)

Program Coordinator
Provo Area Office
PRO-720
Provo, UT

(801) 379-1069 (phone)

State Water Conservation Programs

Program Coordinator
Utah Division of Water Resources
P.O. Box 146201
Salt Lake City, UT 84114-6201

(801) 538-7259 (phone)

State Office of County Cooperative Extension Programs

Utah State University
Cooperative Extension Services
Logan, UT 84322

(801) 750-2200 (phone)

USDA State Conservationist

State Conservationist
Natural Resources Conservation Service
W.F. Bennett Federal Building
125 S. State Street
Room 4402
Salt Lake City, UT 84138

(801) 524-5050 (phone)

Washington

USBR Regional and Area Office Water Conservation Program Coordinators

Program Coordinator
Pacific NorthWest Regional Office
PN-6430, 1150 N. Curtis Road
Boise, ID 83706-1234

(208) 378-5280 (phone)

Program Coordinator
Upper Columbia Area Office
UCA-1800, P.O. Box 1749
Yakima, WA 98907-1749

(509) 575-5848 ext. 225 (phone)

Program Coordinator
Lower Columbia Area Office
LCA-3200, 1503 NE 78th Street
Vancouver, WA 98665-9667

(541) 389-6541 (phone)

State Water Conservation Programs

Program Coordinator
Washington Department of Ecology
P.O. Box 47600
Olympia, WA 98504-7600

(360) 407-6637 (phone)

State Office of County Cooperative Extension Programs

Washington State University
WSU Cooperative Extension
College of Agriculture and Home Economics
Pullman, WA 99164

(509) 335-2811 (phone)

USDA State Conservationist

State Conservationist
Natural Resources Conservation Service
West 316 Boone Avenue, Suite 450
Spokane, WA 99201-2348

(509) 353-2337 (phone)

Wyoming

USBR Regional and Area Office Water Conservation Program Coordinators

Program Coordinator
Great Plains Regional Office
GP-2500, P.O. Box 36900
Billings, MT 59107-6900

(406) 247-7707 (phone)

Program Coordinator
Wyoming Area Office
WY-400, P.O. Box 1630
Mills, WY 82644-1630

(307) 261-5676 (phone)

State Water Conservation Programs

Director of Policy and Administration
Wyoming State Engineer's Office
Herschler Building, 4E
Cheyenne, WY 82002

(307) 777-5927 (phone)

State Office of County Cooperative Extension Programs

University of Wyoming
Cooperative Extension Services
PO Box 3354
Laramie, WY 82071-3354

(307) 766-5124 (phone)

USDA State Conservationist

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Federal Office Building
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Casper, WY 82601-1911

(307) 261-6453 (phone)